UNIVERSITY OF MALTA
FACULTY FOR HEALTH SCIENCES

Submission of Dissertation/Thesis for Examination

Student's ID/Code ____

Student's Name & Surname ______________________________________

Course ____

Title of Dissertation/Thesis____________________________________

____

____

I am hereby submitting my dissertation/thesis for examination by the Board of Examiners.

_______________________ _______________________

Signature of Student Date

Submission noted.

_______________________ _______________________

PROF CARMEL J. CARUANA Date

DEVELOPMENT OF AN INVENTORY OF BIOMEDICAL IMAGING PHYSICS LEARNING OUTCOMES FOR MRI RADIOGRAPHERS IN MALTA

JOSEPH CASTILLO

A thesis submitted in partial fulfilment
for the degree of Doctor of Philosophy

University of Malta
Faculty of Health Sciences

September 2017

Abstract

The purpose of this study was to develop an inventory of biomedical imaging physics knowledge and skills learning outcomes for MRI radiographers in Malta using a multistakeholder, consensus based approach.

The study adopted a sequential mixed methods approach, through five main steps:

In step 1, a set of semi-structured interviews followed by a Delphi process were used to forecast the MRI service portfolio for Malta for the year 2020. A multi-stakeholder expert group agreed that the current MRI service catalogue should be maintained (median = 6.0 on a six-point level of agreement Likert scale, interquartile range (IQR) as a measure of level of consensus ≤ 1.0), whilst introducing specific new services such as guided breast biopsies (median = 6.0, IQR = 1.0), tractography (median = 5.0, IQR = 1.0) and oncology planning (median = 5.0, IQR = 1.0). A median ≥5 signified a high level of agreement with the Delphi statements whilst an IQR ≤ 1.0 signified a high level of consensus among the participants on that particular level of agreement.

In step 2, a Nominal Group Technique was used to optimise the MRI care pathway used in Malta and identify the quality criteria at each stage. The care pathway was again evaluated by a multistakeholder group of participants and suggested improvements to the care pathway ranked in order of importance. The participants attached the highest importance (> 70 on a level of importance scale of 0 - 100) to benchmarking, defining quality criteria, setting a safety checklist and MR education for referrers. The introduction of a radiographer technical report and documentation of patient pain levels prior to MRI were novel themes proposed by the participants.

In step 3 a cross sectional qualitative documentary survey of MRI competence profiles and qualification and certification frameworks in 6 major English speaking countries was carried out with an emphasis on the identification of elements of good practice. New Zealand, Canada, United States and United Kingdom have well established national competence profiles. New Zealand and Canada are in the process of updating their competence profiles. In the majority of countries, the competence profiles are used by educational institutions as a basis for developing MRI course learning outcomes. In New Zealand, Canada and United Stated the competence profile is used by the registration body to design the board registration examination.

In Step 4 an MRI competence profile was developed specifically for Maltese MRI radiographers based on the results of steps 1 to 3 and validated with a multi-stakeholder Delphi group. A high level of agreement and consensus (median ≥ 5.0, IQR ≤ 1.0) was obtained for 37 of the 43 competence statements categorized under 7 key activities namely image acquisition, education, risk management, service unit management, facility management, quality assurance and research in the first Delphi round. In the second Delphi round three further competence statements achieved the desired levels of agreement and consensus, whilst three statements retained a low level of consensus (IQR = 1.5). Further analysis showed that absence of consensus for these three competences was the result of a difference in opinion between radiographers and radiologists.

In the final step 5, an inventory of biomedical imaging physics knowledge and skill learning outcomes required by MRI radiographers to deliver the competence profile was developed via a document analysis of textbooks and the research literature. This was subsequently validated by a multi-stakeholder expert group. An inventory of 324 physics learning outcomes closely integrated with the competence profile was validated using a dichotomous agree/do not agree level of agreement scale and a level of consensus ≥70%.

The inventory of biomedical imaging physics learning outcomes for MRI radiographers developed and validated in this thesis is the first that has been based on a formal comprehensive research process in Malta and probably worldwide. The research process used in the development of the learning outcomes is sufficiently generic to be easily adapted to the development of physics learning outcomes for other radiography and radiology specialties and possibly other health care professions.

Keywords: learning outcome inventory, MRI physics knowledge and skills, consensus methods, MRI radiographers, competence profile, magnetic resonance education, certification, qualification, service portfolio, and care pathways.

Acknowledgements

This has been a six-year long journey.

I am extremely grateful to my principal supervisor Professor Carmel J. Caruana and the multidisciplinary Advisory Board of Experts: Professor Paul S. Morgan (medical physicist), Dr Catherine Westbrook (radiographer) and Dr Adrian Mizzi (consultant radiologist); each has added something of their own to the resulting thesis. I would also like to thank the many participant experts who have taken time to contribute to this study. I would like to collectively thank the MRI radiographers and other stakeholders both overseas and local who helped pilot the tools used for this study.

I gratefully acknowledge the funding received through the Malta Government Scholarship Scheme to undertake this PhD project.

My heartfelt thanks to my longsuffering family, particularly, Angela, my wife, for her understanding and patience. I will now be able to spend weeks catching up on those many tasks that have been delayed.

Finally, I am grateful to four of my best friends who were an inspiration but probably did not realise: Mr Simon Grech who also proofread this manuscript, Ms Tina Zec, Mr Patrick Muscat, and Mr Alfred Galea. Thank you all.

Finally, a quotation from Jigoro Kano, creator of Judo, which applies to every discipline and perhaps also to research:

> *The final goal of Judo is to perfect yourself and contribute something of value to the world.*

UNIVERSITY OF MALTA

FACULTY OF HEALTH SCIENCES

Declaration of Authenticity for Doctoral Students

Student's I.D. /Code ______________________________

Student's Name & Surname ____

Course ____

Title of Dissertation/Thesis ____

____

____

I hereby declare that I am the legitimate author of this Dissertation/Thesis and that it is my original work.

No portion of this work has been submitted in support of an application for another degree or qualification of this or any other university or institution of higher education.

I hold the University of Malta harmless against any third party claims with regard to copyright violation, breach of confidentiality, defamation and any other third party right infringement.

As a Ph.D. student, as per Regulation 49 of the Doctor of Philosophy Regulations, I accept that my thesis be made publicly available on the University of Malta Institutional Repository.

_______________________   _______________________

Signature of Student   Date

Contents

Operational definitions

Aligned or Coherent curriculum	refers to an academic program that is (1) well organized and purposefully designed to facilitate learning, (2) free of academic gaps and needless repetitions, and (3) aligned across lessons, courses, subject areas, and grade levels. Retrieved from http://edglossary.org/hidden-curriculum.
Biomedical Imaging	The science and the branch of medicine concerned with the development and use of imaging devices and techniques to obtain internal anatomic images and to provide biochemical and physiological analysis of tissues and organs. (http://www.nlm.nih.gov/tsd/acquisitions/cdm/subjects15.html)
Biomedical Physics	The use of physics concepts, theories and methods for the greater understanding and development of clinical practice and experimental medicine (Caruana et al., 2009).
Certification	The process of formally validating knowledge, skills and competences acquired by an individual, following a standard assessment procedure. Certificates or diplomas are issued by accredited awarding bodies (European Commission., 2007).
Competence	The proven ability to use knowledge, skills and other abilities to perform a function against a given standard in work or study situations and in professional and/or personal development. In the EQF, 'competence' is described in terms of ***responsibility and autonomy*** (European Parliament and Council, 2008).
Competence Profile	A list of key responsibilities for a given class of health care professionals.
Curriculum	Inventory of activities related to the design, organisation and planning of an education or training action, including definition of learning objectives, content, methods (including assessment) and material, as well as arrangements for training teachers and trainers (The European Centre for the Development of Vocational Training, 2014).
European Qualification Framework (EQF)	A translation device to make national qualifications more readable across Europe, promoting workers' and learners' mobility between countries and facilitating their lifelong learning. Includes definitions of learning outcomes, knowledge, skills and competence (European Parliament and Council, 2008).
Formal learning	Learning that occurs in an organised and structured environment (in a school/training centre or on the job) and is explicitly designated as learning (in terms of objectives, time or resources). Formal learning is intentional from the learner's point of view. It typically leads to certification (European Commission., 2007).

Informal learning	Learning resulting from daily activities related to work, family or leisure. It is not organised or structured in terms of objectives, time or learning support. Informal learning is in most cases unintentional from the learner's perspective. It typically does not lead to certification (European Commission., 2007).
Knowledge	The outcome of the collection and assimilation of information through learning. In the EQF, knowledge is described as theoretical and/or factual (European Parliament and Council, 2008).
Learning Outcomes	Statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence (European Parliament and Council, 2008).
Learning Outcomes Inventory	List of knowledge, skills and competence statements an individual has acquired and/or is able to demonstrate after completion of a learning process, either formal, non-formal or informal.
Lifelong learning	All learning activity undertaken throughout life, with the aim of improving knowledge, skills and/or qualifications for personal, social and/or professional reasons (European Commission., 2007).
Mini-states	A small independent state with a population of less than a million (Eccardt, 2005).
Non-formal learning	Learning which is embedded in planned activities not explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contain an important learning element. Non-formal learning is intentional from the learner's point of view. It normally does not lead to certification (European Commission., 2007).
Patient care pathway	A complex intervention for the mutual decision making and organization of predictable care for a well-defined group of patients during a well-defined period. Defining characteristics of pathways include: an explicit statement of the goals and key elements of care based on evidence, best practice and patient expectations; the facilitations of the communication and coordination of roles and sequencing the activities of the multidisciplinary care team, patients and their relatives; the documentation, monitoring, and evaluation of variances and outcomes; and finally the identification of relevant resources (The European Pathway Association, http://www.e-p-a.org).
Planned curriculum	Documents that shape the content to be covered when teaching. These documents arise out of policy environments and reflect what is deemed required or necessary for students to learn at specific levels of education or educational settings (Murphy &

	Pushor, 2010).
Qualification	means a formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards (European Commission., 2007; The European Centre for the Development of Vocational Training, 2014).
Service	All clinical services offered by large tertiary healthcare institutions such as clinical procedures, educational services to referrers (including self-referrals) and general public, service development oriented research activities.
Service management	A total organisation approach that makes quality of service, as perceived by the customer, the number one primary driving force for the operation of the business (Morten & Peter, 2014).
Service Portfolio	The complete set of services that are managed by a service provider. The service portfolio is used to manage the entire lifecycle of all services, and includes three categories: service catalogue (current or available for development), service pipeline (proposed or in development) and service retired (Educause Center for Analysis and Research Working Group, 2015).
Service Unit	A business unit that has been approved to provide goods and/or services.
Skills	The ability to apply knowledge and use know-how to complete tasks and solve problems. In the EQF, skills are described as cognitive (use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments) (European Parliament and Council, 2008).
Syllabus	A list of the topics or books that will be studied in a course (Merriamwebster.com).

Acronyms

A&E	Accident and Emergency
ABoE	Advisory Board of Experts
AEIRS	Association of Educators in Imaging and Radiologic Sciences
AIR	Australian Institute of Radiography
ALs	Action Levels
ARMRIT	American Registry of Magnetic Resonance Imaging Technologists
ARRT	American Registry of Radiological Technologists
ASRT	American Society of Radiological Technologists
BSc	Bachelor of Science
BSSFP	Balanced Steady State Free Precession
CAMRT	Canadian Association of Medical Radiation Technologists
CATS	Credit Accumulated Transfer Scheme
CHEA	Council for Higher Education Accreditation
CoR	College of Radiographers
CPD	Continuous Professional Development
CSR	Clinical Specialist Radiographer
CT	Computed Tomography
ECR	European Congress of Radiology
EFRS	European Federation of Radiographer Societies
EHEA	European Higher Education Area
ELVs	Exposure Limit Values
EPI	Echo Planar Imaging
EQF	European Qualification Framework
ESMRMB	European Society of Magnetic Resonance in Medicine and Biology
ESR	European Society of Radiology
FGE	Fast Gradient Echo
GBCA	Gadolinium Based Contrast Agent
HCPC	Health and Care Professions Council
HE	Higher Education
HENRE	Higher Education Network for Radiography in Europe

IAEA	International Atomic European Agency
IIRRT	Irish Institute of Radiography and Radiation Therapy
IPE	Inter-professional Education
IQR	Interquartile range
ISMRM	International Society of Magnetic Resonance in Medicine
ISRRT	International Society of Radiographers and Radiological Technologists
JRCERT	Joint Review Committee on Education in Radiologic Technology
KSC	Knowledge, Skills and Competences
LS	Likert scale
MDH	Mater Dei Hospital
MEDRAPET	Medical Radiation Protection Education & Training
MHRA	Medicines and Healthcare products Regulatory Agency
MID	Medical Imaging Department
MMRRG	Malta Magnetic Resonance Radiography Group
MPE	Medical Physics Expert
MRI	Magnetic Resonance Imaging
MRMD	Magnetic Resonance Medical Director
MRPBA	Medical Radiation Protection Board of Australia
MRRD	Magnetic Resonance Research Director
MRSO	Magnetic Resonance Safety Officer
MRTB	Medical Radiation Technologists Board
MSc	Master of Science
NGT	Nominal Group Technique
NM	Nuclear Medicine
PACS	Picture Archiving Communication System
PET	Positron Emission Tomography
PGDip	Post Graduate Diploma
REA	Registration Examination Assessment
RIS	Radiology Information System
RPE	Radiation Protection Expert
RPO	Radiation Protection Officer
SAR	Specific Absorption Rate

SME	Subject Matter Expert
SMRT	Section of Magnetic Resonance Technologists
SoR	Society of Radiographers
SSFSP	Single Shot Fast Spin Echo
UCD	University College Dublin
UK	United Kingdom
US	United States
USI	Ultrasound Imaging
USDE	United States Department of Education
VET	Vocational Education Training
WHO	World Health Organization

Author Publications / Presentations arising from or related to this research

Articles (copies can be found in Appendix I)

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C., & Mizzi, A. (2017). An international survey of MRI qualification and certification frameworks with an emphasis on identifying elements of good practice. Radiography, 23(1), 8 – 13.

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C., & Mizzi, A. (2016). MRI Care Pathway: Supporting a Quality Management System. HealthManagement, Volume 16 - Issue 1.

Castillo, J., Caruana, C. J., Morgan, P. S., & Westbrook, C. (2015b). Optimizing a magnetic resonance care pathway: A strategy for radiography managers. Radiography, 21(1), 29-33.

Castillo, J., Caruana, C. J., Morgan, P. S., & Westbrook, C. (2015a). Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020. Radiography, 21(1), 21-27.

Castillo, J., & Caruana, C. J. (2014). Maltese radiographers' attitudes towards continuing professional development: an initial study using concept maps. Journal of Medical Imaging and Radiation Sciences, 45(1), 37-46.

Castillo, J., Caruana, C. J., & Wainwright, D. (2011). The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level. Radiography, 17(3), 230-234.

Conference presentations

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C., & Mizzi, A. (2016). Validation of a competence profile for MR radiographers using a formal research process. European Congress of Radiology, Vienna (**Award Winner – Radiographer Session; A copy can be found in Appendix J**).

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C., & Mizzi, A. (2016). Developing content of health care curricula using a multi-stakeholder research-based approach. 2nd National symposium of health sciences, Malta.

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C. (2014) Service development by radiographer managers: a case study in MRI service portfolio development through a formal research-based process. European Congress of Radiology, Vienna

Poster presentations

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C. Mizzi A. (2015) Qualification and Certification frameworks for MRI radiographers in the major English-speaking countries. 9th Malta Medical School Conference, Malta.

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C. Mizzi A. (2015) An MRI care pathway for Malta. 9th Malta Medical School Conference, Malta.

Castillo, J., Caruana, C. J., Morgan, P. S., Westbrook, C. (2014) Developing the Magnetic Resonance (MR) Care Pathway using formative research. National Symposium for Health Services. Malta.

Citations of publications and presentations arising from or related to the study

Eccles, C. L., McNair, H. A., Armstrong, S. E. A., Helyer, S. J., & Scurr, E. D. (2017). In response to Westbrook – Opening the debate on MRI practitioner education. *Radiography, 23*(Supplement 1), S75-S76.

England, A., Geers-van Gemeren, S., Henner, A., Kukkes, T., Pronk-Larive, D., Rainford, L., & McNulty, J. P. (2017). Clinical radiography education across Europe. *Radiography, 23*(Supplement 1), S7-S15.

Garneau, A. B., Lavoie, P., & Grondin, M. (2017). Dichotomy and dialogue in conceptualizations of competency in health professionals' education. *Journal of Nursing Education and Practice, 7*(6), 18.

ohn-Matthews, J. S., Wallace, M. J., & Robinson, L. (2017). The Delphi technique in radiography education research. *Radiography, 23*(Supplement 1), S53-S57.

Nightingale, J. (2017). Thinking differently about specialist imaging education. *Radiography*, *23*(3), 179-180.

Vanckavičienė, A., Macijauskienė, J., Blaževičienė, A., Basevičius, A., & Andersson, B. T. (2017). Assessment of radiographers' competences from the perspectives of radiographers and radiologists: a cross-sectional survey in Lithuania. *BMC medical education, 17*(1), 25.

Wareing, A., Buissink, C., Harper, D., Gellert Olesen, M., Soto, M., Braico, S., Van Laer, P., Gremion, I., & Rainford, L. (2017). Continuing professional development (CPD) in radiography: A collaborative European meta-ethnography literature review. *Radiography, 23*(Supplement 1), S58-S63.

Westbrook, C. (2017). Opening the debate on MRI practitioner education – Is there a need for change? *Radiography, 23*(Supplement 1), S70-S74.

Holmström, A., & Ahonen, S.-M. (2016). Radiography students' learning: a literature review. *Radiologic technology, 87*(4), 371-379.

Levant, Y., Coulmont, M., & Sandu, R. (2016). Business simulation as an active learning activity for developing soft skills. *Accounting Education, 25*(4), 368-395.

McNulty, J. P., Rainford, L., Bezzina, P., Henner, A., Kukkes, T., Pronk-Larive, D., & Vandulek, C. (2016). A picture of radiography education across Europe. *Radiography, 22*(1), 5-11.

Walsh, R., & Craig, A. (2016). Radiation Therapists' and Diagnostic Radiographers' participation in continuing professional development and knowledge of Regulatory Body Registration. *Journal of Radiotherapy in Practice, 15*(2), 150-160.

Biljana, L. (2015). *Analiza ishoda učenja kao indikatora kvaliteta visokog obrazovanja.* Универзитет у Новом Саду, Филозофски факултет (Faculty of Philosophy, Novi Sad).

Cunningham, J., Wright, C., & Baird, M. (2015). Managing clinical education through understanding key principles. *Radiologic technology, 86*(3), 257-273

Drechsler, A., & Sati, T. (2015). A Competence-Focused Assessment Framework for Project Management Certifications presented at Twenty-first Americas Conference on Information Systems, Puerto Rico.

Knox, S., Dunne, S., Cullen, W., & Dunne, C. P. (2015). A qualitative assessment of practitioner perspectives post-introduction of the first Continuous Professional Competence (CPC) guidelines for emergency medical technicians in Ireland. *BMC Emergency Medicine, 15*(1), 11.

Lundvall, L.-L., Abrandt-Dahlgren, M., & Wirell, S. (2015). How do technical improvements change radiographers' practice–A practice theory perspective. *Radiography, 21*(3), 231-235.

Moreira, I. C., Ventura, S. R., Ramos, I., & Rodrigues, P. P. (2015). Development and assessment of an e-learning course on breast imaging for radiographers: a stratified randomized controlled trial. *Journal of medical Internet research, 17*(1).

Rose, C., & McIntosh, J. (2015). Developing Clinical Competence in Diagnostic Imaging Students. *Radiologic technology, 87*(2), 230-235.

Vanckavičienė, A. (2015) *Radiologijos technologų pasiūlos ir poreikio prognozė 2012–2030 m. Bei kompetencijų tyrimas.* (PhD thesis), Lithuanian University of Health Sciences.

Hukkanen, T. (2013). *Röntgenhoitaja suoradigitaalisen natiiviröntgenlaitteen hankintaprosessissa.* (master's thesis), Metropolia University of Applied Sciences, Finland..

Caruana, C. J. (2012). The Ongoing Crisis in Medical Device Education for Healthcare Professionals: Breaking the Vicious Circle Through Online Learning. *International Journal of Reliable and Quality E-Healthcare (IJRQEH), 1*(2), 29-40.

Pant, L. P. (2012). Learning and innovation competence in agricultural and rural development. *The Journal of agricultural education and extension, 18*(3), 205-230.

Pawsey, M. (2012). *Perehtyvän röntgenhoitajan osaamisen kriteerit tietokonetomografiatyössä: itsearviointimittarin kehittäminen HUS-Kuvantamisen tietokonetomografiayksiköihin.* (master's thesis), Metropolia University of Applied Sciences, Finland.

Walta, L. (2012). *Potilaan hoitaminen diagnostisessa radiografiassa ja sen kuormittavuus röntgenhoitajan arvioimana-tavoitteena inhimillinen ja turvallinen kuvantamistapahtuma.* (master's thesis), University of Turku, Faculty of Medicine, Finland.

Chapter 1: Introduction to the study

1.1 Introduction

This work concerns the development of an inventory of MRI biomedical imaging physics learning outcomes for MRI radiographers in Malta through a collaboration of relevant stakeholders. Advanced curriculum development for medical imaging education is sometimes inextricably linked solely to higher educational institutions, but the World Health Organization recommends collaborations among Ministries of Health, Ministries of Education, public and private training institutions and health professional organizations (World Health Organization, 2006). This study therefore was conducted using a range of collaborative data collection and consensus based validation techniques with a range of MRI stakeholders.

This chapter presents the problem statement followed by a background to the issues identified in the problem statement, a description of the research context, the objectives of the study, the scope of the study, the relevance of the study, the theoretical conceptual frameworks and philosophical perspectives guiding the study, research design, selection of participants, literature databases, ethical responsibilities and core values, the researcher's location in the research context and the Advisory Board of Experts that helped guide the study.

1.2 Problem statement

The rapid expansion in imaging technology, the promulgation of new European legislation and role development aspirations of the various professions practicing within diagnostic and interventional imaging is leading to change in the role of diagnostic radiographers across Europe (Cowling, 2008). In particular, in some countries radiographers are moving towards a higher role in the management of medical imaging service units devoted to the special modalities i.e., CT, MRI, NM and USI (Pallan et al., 2005; Miller et al., 2011). The same is true in Malta where MRI radiographers also aspire to a higher role in image acquisition, safety, scientific and technological aspects of the service and in the management of MRI units. Such an elevated level role however requires a higher level of imaging physics expertise owing to added responsibilities such as service development which would involve increased liaison with physicists and engineers. In health care organizations increased expertise is generally acquired through continuous professional development (CPD) courses. Unfortunately, it is becoming increasingly difficult to provide time off for CPD attendance owing to higher workloads and in certain cases reduced staffing levels. In such circumstances, it is advisable that CPD time is optimized by ensuring that CPD content (expressed as an inventory of learning outcomes) is determined after a formal study which aims to ensure that such content reflects closely the particular learning needs of the specific MRI radiography community being served. Regrettably no such inventory has been developed for biomedical imaging physics for MR radiographers in Malta. The principal objective of this study was therefore to develop such an inventory.

1.3 Background to the study

Over the past few decades with the advent of computers and image processing, diagnostic imaging has gone through rapid changes specifically with the introduction of computed tomography (CT), magnetic resonance imaging (MRI), digital projection radiography and the growth of ultrasonography (Filler, 2010). Today's radiographers are expected to master a plethora of imaging technologies and protocols that are far greater than those available a few decades ago. Up to the early 70's the only imaging technology that was easily accessible was film projection radiography and this was reflected in the less extensive radiography physics curricula of the time (Harris et al., 1995) .

The increased versatility and capacity of imaging techniques now allows more patients to be scanned faster and cheaper increasing concerns regarding exposure to ionising radiation in the case of x-rays and strong magnetic fields and electromagnetic frequencies in the case of MRI (Brix et al., 2003; Silva et al., 2006; Brody et al., 2007; Karpowicz et al., 2007; Fazel et al., 2009). As regards to ionising radiation protection, European legislation has always followed ICRP recommendations whereby justification, optimization and dose limitation are considered the cornerstone for the effective and safe use of ionising radiation. The Euratom directives stipulate that member states shall establish an adequate legislative and administrative framework for providing appropriate ionising radiation protection education, training and information to all individuals whose tasks require specific competences in radiation protection (Education and Training in Radiological Protection, 2009; European Commission, 2012, 2014). In a similar manner the increased use of MRI has also led the European Commission to introduce directive 2013/35/EU that aims to protect workers from the adverse effects of exposure to electromagnetic fields (European Parliament and the Council of European Union, 2013). Employers are required to ensure that risks arising from electromagnetic fields at work are eliminated or reduced to a minimum by adhering to exposure limit values (ELV) and action levels (AL). Article 6 of the same directive requires the employer to ensure that workers who are likely to be exposed to risks from electromagnetic fields at work shall receive training (Keevil et al., 2014). In response to the above and also patient safety a Working Group made up of representatives from the International Society of Magnetic Resonance in Medicine (ISMRM) on MR Safety agreed on a document which aimed at facilitating the implementation of a suitable organizational structure for ensuring safety in and around MR imaging systems The document laid down the responsibilities for MR safety for the MR Medical Director (MRMD) or MR Research Director (MRRD), the MR Safety Officer (MRSO), and the MR Safety Expert (MRSE) (Calamante et al., 2016).

Although the radiography profession attempts to project an image of a homogenous community across the world, the role of the radiographer is in fact quite diverse and the level of development of the profession is very variable (Cowling, 2008). A few countries led by UK and USA have suggested models for extended roles for radiographers and aspects of these models have been used by radiographers in other countries in their quest to develop their role at the national level (Cowan et al., 2007; Smith & Baird, 2007). Since education is pivotal to role progressions, the International Society of Radiographers and Radiological Technologists (ISRRT) was asked to investigate the possibility of agreed international standards for radiography educational programs for entry to the profession (ISRRT, 2005; Cowling, 2008). The resulting document 'Guidelines for the Education of Entry Level Professional Practice in Medical Radiation Sciences' recommended the academic degree as entry level qualification for the profession but acknowledged the existing variability (ISRRT, 2005). This variability is also pronounced in the European Union where differences in educational levels are still an impediment to any Europe-wide role harmonisation (ISRRT, 2004; Cowling, 2008).

In the case of role development and learning in MRI this variability is even more pronounced (Castillo et al., 2017). This is a consequence of the fact that notwithstanding the complexity of the technology, MRI certification is not in general a prerequisite to practice in many countries. The present state of MRI education for radiographers in Europe exhibits a level of expertise that is so diverse that serious doubts have been raised about the effectiveness and safety of present practice even at the basic level, let alone at the higher levels targeted in this study (Westbrook & Talbot, 2009). Grave concern has been expressed that often the education of this group of radiographers is largely provided simply 'in-house' and in an ad hoc fashion by other radiographers (who are often themselves often insufficiently knowledgeable) or short demonstration sessions by 'applications specialists' provided by equipment vendors. Such training is usually informal, focuses solely on essential safety training and basic use of scanner software – and rarely assessed (Westbrook & Talbot, 2009; Ribeiro et al., 2010; Moberg, 2013; Opoku et al., 2013). Very little educational research has been carried out or published on MRI education for radiographers. Indeed, a comprehensive search of the English literature at the start of this project resulted in only three research articles regarding the status of MRI education (Piper & Buscall, 2008; Westbrook & Talbot, 2009; Moberg, 2013).

Regrettably, a thorough search of the English literature by Caruana and Castillo (2010) resulted in not a single published article dedicated to the education of MRI physics for radiographers. In particular, no comprehensive inventory of biomedical imaging physics learning outcomes targeted to MRI radiographers and developed through a published formal research process was found. Although MRI curricular documents have been published by the Canadian Association of Medical Radiation

Technologists (Canadian Association of Medical Radiation Technologists, 2008), the American Registry of Radiological Technologists (American Registry of Radiologic Technologists, 2009), the American Society of Radiological Technologists (American Society of Radiologic Technologists, 2010) and the Sector Skills Council for Health in the UK (Skills for Health, 2007), these often consist simply of syllabus style lists of topics as opposed to structured learning outcome inventories based on service portfolios to be delivered, optimization of patient pathways, associated competence profiles and underpinning knowledge and skills. Moreover, there is no evidence that the aforementioned syllabi were developed through a formal research process. Certainly none of the inventories are formulated in the knowledge-skills-competence (KSC) learning outcome format demanded by the European Qualification Framework (EQF) for lifelong learning (European Commission, 2008). In addition, often they do not address the extended role of service development required of radiographers practicing at higher level roles. At the European level, the Higher Education Network for Radiography in Europe (HENRE, 2001) has developed and published an inventory of agreed generic and subject specific competences for the first cycle of radiography education (Challen, 2008) and early in 2017 the European Federation of Radiography Societies (EFRS) published learning outcomes for the second Masters cycle where MRI specialization is usually found (European Federation of Radiographer Societies, 2017). However, the document does not provide speciality specific learning outcomes and simply serves as a generic benchmark to institutions that currently offer, or are in the process of developing, Radiography educational programmes at EQF Level 7 (European Federation of Radiographer Societies, 2017). The only publication that provides specific learning outcomes at these higher levels is that of Caruana and Plasek (2006a), but this is limited to the imaging physics component and would now be considered as incomplete and outdated (Caruana, personal communication, 2011). In this case the learning outcomes were illustrated through application to CT and not MRI.

In the meantime, in some countries, owing to changes in practice as a result of increase in demands and role development, MRI radiographers may be required to work autonomously, share clinical responsibility with the radiologist, technical responsibility with the medical physicist and to be responsible for the execution of the entire radiological examination (Bodil et al., 2008; Piper & Buscall, 2008; Australian Institute of Radiography, 2010). In order to produce an image of sufficient quality for accurate diagnosis and in a safe manner, in the shortest time possible and least employment of resources the MRI radiographer needs to understand the clinical question and be able to optimize the scanning protocol (Woodward, 2000). Essential to all this is a workforce educated within programmes which include an extended and comprehensive inventory of MRI physics learning outcomes.

1.4 Research context

Imaging facilities in Malta with a focus on MRI

A brief analysis of the Maltese health service and in particular medical imaging will be helpful to the reader to understand the context within which the study is situated.

The Maltese Government provides a comprehensive health service to all Maltese residents that is entirely free at the point of delivery. This health service, introduced in 1980, is mainly funded from general taxation and to some extent from national insurance contributions (Muscat, 1999). Persons with a low income are 'means tested' by the Department of Social Security and if they qualify for assistance, they receive a card which entitles them to free medicinals. Moreover, a person who suffers from one or more of a specified list of chronic diseases (e.g., rheumatoid arthritis) is also entitled to receive free treatment for any ailment, irrespective of financial means (Formosa, 2006).

Primary health care is delivered mainly through nine health centres (eight in Malta and one in Gozo) that offer a full range of preventive, curative and rehabilitative services. Throughout the years general practitioner and nursing services have been supplemented by various specialised services that include antenatal and postnatal, baby clinics, gynaecological, diabetes, ophthalmic, psychiatric, podiatric, physiotherapy, and speech therapy-language pathology clinics (Formosa, 2006). All the health centres are equipped with direct digital X-ray equipment providing general radiography linked to the main picture archiving communications system (PACS) at Mater Dei Hospital.

The public primary care system works side by side with a thriving private sector and patients can opt for the services of private general practitioners and specialists who work in the primary care setting.

Secondary care and tertiary care are mainly provided from a number of public hospitals, the principal one being the main general hospital located in Malta (Mater Dei Hospital) with a capacity of 928 beds. This hospital opened its doors in November 2007, and is located adjacent to the University of Malta. Together with the other public hospitals it serves as the main teaching hospital to the various health care professions. The Faculties of Health Sciences, Medicine and Dentistry of the University of Malta are largely housed within this hospital.

Another 88 beds are available at the Sir Anthony Mamo Oncology Centre, inaugurated in 2015, 563 beds (short/long stay) at Mount Carmel hospital (which provides psychiatric services) and 271 beds at Karin Grech Hospital that provides geriatric rehabilitation services. A general hospital on the sister island of Gozo provides 259 short/long stay beds.

The medical imaging department (MID) at Mater Dei Hospital is the largest imaging department in Malta. The MID is a filmless department using direct digital imaging in all modalities. Housed within MID are three fluoroscopy units, five general radiography units, five ultrasound machines, one 1.5T and one 3T magnetic resonance scanner (installed 2014), 2 CT scanners, 1 PET/CT scanner, 2 gamma camera units, 7 mobile x-ray machines and nine image intensifiers. There is also an x-ray unit at the adjacent admitting and emergency (A&E) department. The management of the MID is also responsible for coordinating the radiological services in health centres and the Karen Grech Rehabilitation hospital. The radiological services in the sister island of Gozo also fall under the direct responsibility of the MID.

The public imaging services across Malta and Gozo are coordinated in the ambit of a team system whereby each modality (i.e., CT, MRI, angiography, ultrasound, mammography, health centres, A&E, mobile machines and theatre, bone-densitometry, general radiography and Gozo Hospital) is managed by a team of radiographers under the supervision of a team leader. In May 2017, these modalities were grouped into five sections managed by five advanced allied health practitioners who all report to the professional lead diagnostic radiographer. All teams work together for ensuring training for the professional development of all radiographers including training of entry level radiographers and senior radiographers. This skill mix ensures that services will not be affected by any reduction in staffing levels.

Up to 1995 no MRI systems were available in Malta and patients within the public health system requiring MRI were sent to the United Kingdom by the health authorities. MRI services in Malta started in 1995 when a local private hospital installed a 0.5T Philips Gyroscan NT. Immediately the Maltese health authorities entered into a contract with the management of the private hospital by which it was possible for it to send selected patients to the private hospital concerned. As a result of political developments and as MRI requests increased, pressure mounted on the government to procure its own MRI scanner. This happened in March 2000, when a GE Signa MRI scanner was procured by the Government of Malta. The GE scanner was upgraded several times and overhauled with new hardware and software. In March 2017, the GE Signa MRI scanner was completely refurbished and upgraded to the MRI Explorer and has been instrumental in introducing additional applications. A 3T Philips Ingenia was installed in December 2014 and has been instrumental in introducing new MRI applications. There are no MRI scanners in the health clinics or the Gozo hospital at present.

The government has just launched a development brief that has six deliverables to increase the number of beds and services. These are:

- A completely new 450 bed fully-fledged hospital in Gozo to replace the present one. This will be run by Vitalis group in conjunction with Bart's Medical School which is expected to take the first intake of students in 2018. There are no published plans yet to install an MRI scanner

- Karin Grech Hospital will be changed to a mixed use for geriatric and rehabilitation treatment centres (Grima, 2015).

- A completely new private hospital within St Luke's Hospital area. This hospital will be managed also by Vitalis group, would have its own medical imaging department and would provide beds to the Government of Malta. There are no published plans that this hospital would include an MRI scanner.

In the last nine years, the MRI scanners at the local general hospital have had to cope with a regular increase in requests for MRI services (Figure 1.1).

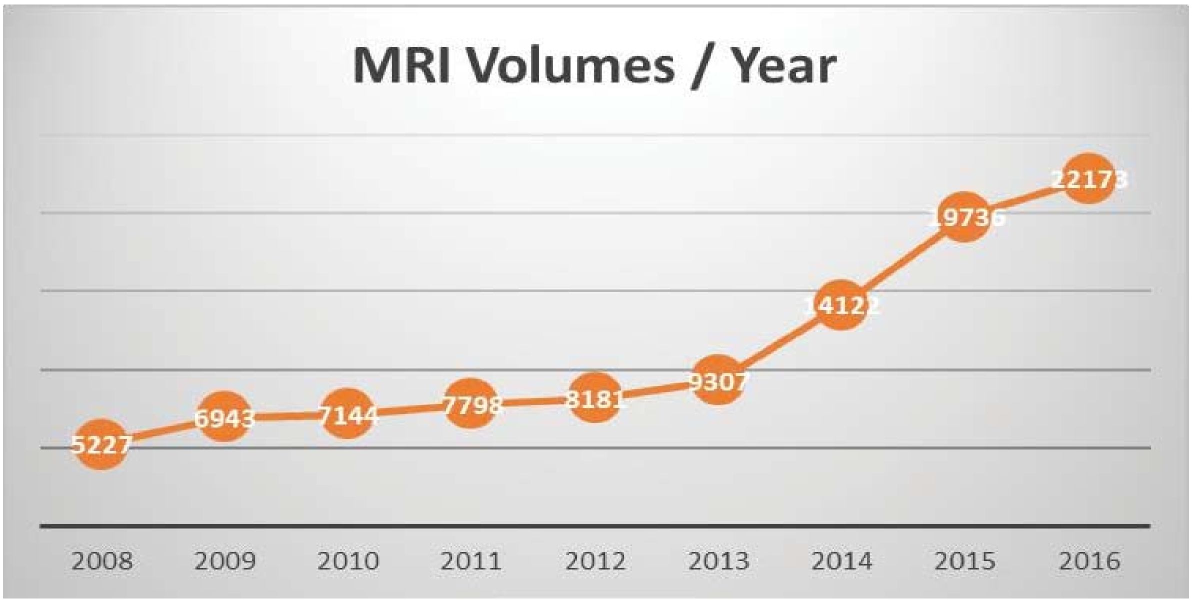


Figure 1.1 Number of MRI procedures by year obtained from Medical Imaging Department statistics

Presently, the MRI unit at MID is covered by a team of ten radiographers working seven hour shifts from seven in the morning till nine in the evening. The team is responsible for the scheduling of patients, safety screening, and share the modification of protocols for addressing specific clinical questions and incidental findings with consultant radiologists. Justification for MRI requests is done by consultant radiologists, but this is not based on formally documented justification guidelines. In addition, clinical audits on the appropriateness of referrals is only carried out as part of resident training but these are infrequent. The MRI radiography team together with the consultant radiologists, lead medical diagnostic radiology physicist and professional lead in diagnostic radiography are also responsible for addressing requests for new services. Amongst the recent new services introduced (since the start of this PhD) were scans for deep brain stimulation, breast imaging, rectal staging, 3D imaging of the brain for radiotherapy planning, liver elastography, prostate and cardiac imaging. These developments require MRI radiographers to have a strong scientific and technological knowledge base, ability to make clinical judgements and the capability to use resources effectively.

On the islands, there are also six private hospitals/clinics that offer secondary care. Altogether, in 2016 they provided 105 beds. In the private sector, there are two 1.5T MRI scanners one being a Siemens Magnetom and the other a Philips Intera. Anecdotal evidence indicates that the number of procedures performed in the private settings has been low. Late in 2011, in order to reduce waiting times, the Maltese government introduced a public-private partnership scheme to outsource a number of MRI procedures. This initiative was supported further with a twilight service introduced in 2013. A group of radiographers and radiologists worked two shifts between 9:00pm and 1:00am and 5am and 7am. With this initiative, the waiting time was reduced from 18 months to 4 months. This explains the sharp increase in the volumes of scans following 2013 (see Figure 1.1).

MRI Education and Training in Malta

MRI education and training in Malta started off during the installation of the first MRI magnet in the public health service in April 2000. The course was organised through the then Institute of Health Care (the precursor of the present Faculty of Health Sciences) under the auspices of the University of Malta. Following this course, in house training was given by a clinical application specialist and by radiographers who formed the core team of MRI. In the period 2000 to 2010 a small group of Maltese radiographers read for an MSc course in MRI at the Anglia Ruskin University. In 2010, the University of Malta started a three-year MSc postgraduate course in MRI. Further MRI education was provided by the Malta Magnetic Resonance Radiography Group established in 2009. This community of MRI radiography practitioners organises courses, seminars and symposia on MRI topics. The following is a list of courses organized by the Malta Magnetic Resonance Group to date:

2010 – MRI in Practice Course – Catherine Westbrook / John Talbot

2011 – Cardiac MRI Course – Oxford MRI Centre

2011 – MRI Physics in Neuroimaging – Dr Emanuel Kanal

2014 – MRI safety course – Dr Emanuel Kanal

2016 – MRI in Practice course – Catherine Westbrook / John Talbot

1.5 Objectives of the study

The aim of this study is to develop an inventory of biomedical imaging physics learning outcomes which is specific to the future learning needs of MRI radiographers in Malta. MRI physics learning outcomes are fundamental for image quality and patient / occupational safety. Such an inventory would need to be expressed in terms of learning outcome statements of the Physics Knowledge and Skills which underpin MRI Radiography Competences as recommended by the European Qualification Framework (EQF) recommendations(Castillo et al., 2011). The inventory would be an essential component of a future national certification and registration scheme for MRI radiographers in Malta.

The specific objectives of the study were the following:

1. To develop and validate a 2020 vision of the MRI service portfolio for Malta. This objective was necessary as the future competence profile and hence physics knowledge and skills learning needs of MRI radiographers should be determined largely by the envisaged future service provision. The results of this objective were published in the journal *Radiography* as ‘Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020’ (Castillo et al., 2015b).

2. To optimize the care pathway for MRI services in Malta. This objective was necessary as the future competence profile and hence physics knowledge and skills learning needs of MRI radiographers will also be heavily influenced by the patient care pathway in MRI. The results of this objective were published in the journal *Radiography* as ‘Optimizing a magnetic resonance care pathway: A strategy for radiography managers’ (Castillo et al., 2015a).

3. To carry out a comparative study of existing competence profiles, qualification and certification frameworks for MRI radiographers in the major English-speaking countries with an emphasis on competence profiles and good practice. This objective was important as it would give an indication of any competence profiles available internationally plus elements of good practice in developing such profiles. The results of this objective were published in the journal *Radiography* as ‘An international survey of MRI qualification and certification frameworks with an emphasis on identifying elements of good practice’ (Castillo et al., 2017).

4. To develop and validate a context specific competence profile for MR radiographers in Malta that would be necessary to deliver the forecasted 2020 MR service portfolio and optimised care pathway developed in Objectives 1 and 2 and inspired by elements of good practice and competence profiles identified in Objective 3.The results of this objective were presented at ECR 2016 and were awarded **best presentation in the section for radiographers** (Castillo et al., 2016)

5. To develop a comprehensive inventory of biomedical imaging physics knowledge and skills learning outcomes to support the competence profile developed in Objective 4. The results of this objective will be submitted for publication late 2017.

The results of objective 5 are the end purpose of the study as expressed in the title of this dissertation title i.e., an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta.

The rationale behind the sequencing of the objectives is also explained graphically below (Figure 1.2).

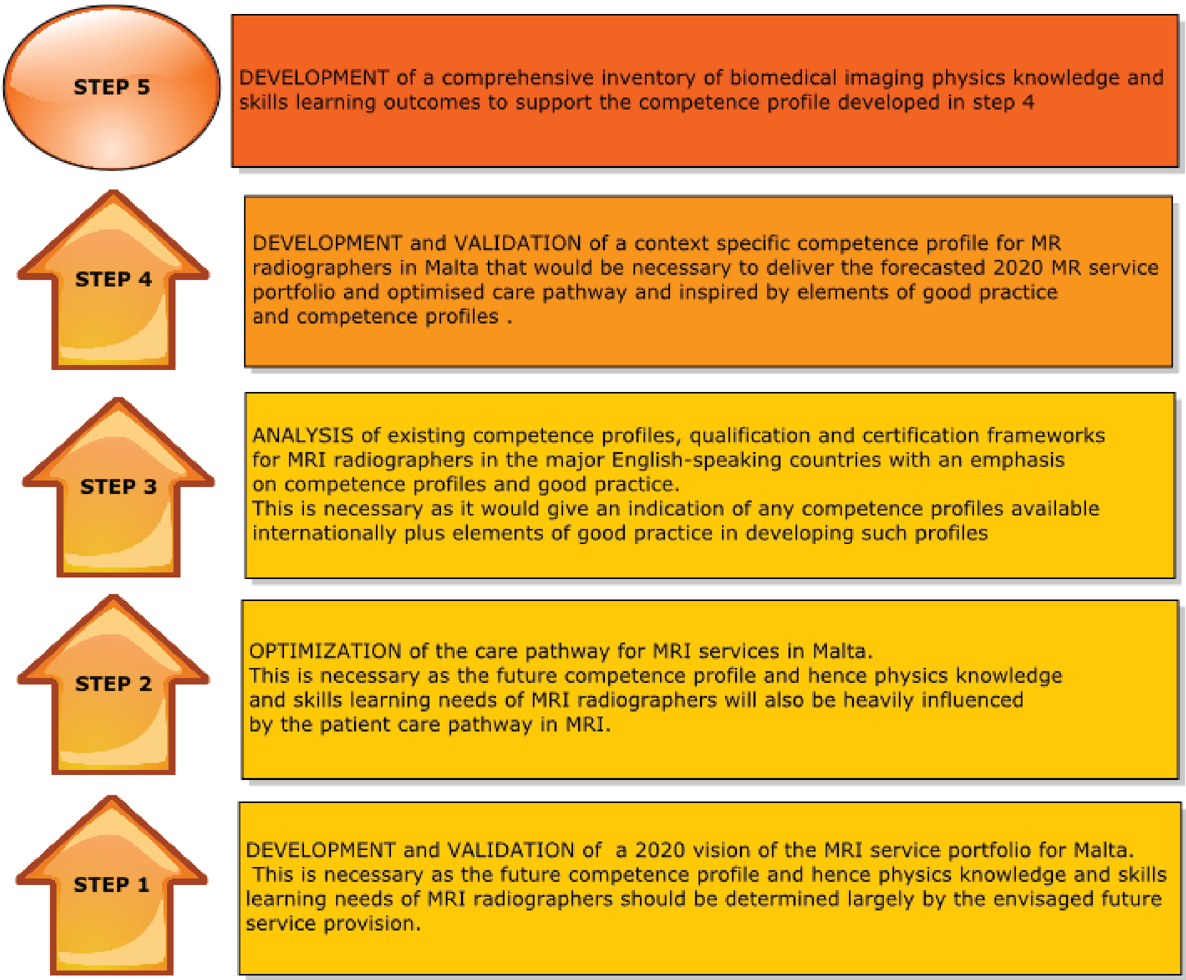


Figure 1.2 A five step strategy to develop and validate an inventory of biomedical imaging physics learning outcomes.

1.6 Scope of the study

The scope of this study will be delimited to the physics learning outcome needs of MRI radiographers in Malta. This study will not include learning outcomes in other areas of study relevant to MRI radiographers such as the human biological sciences, patient care or management which would be the subject of another study.

1.7 Relevance of the study

The relevance of the study for the various stakeholders is as follows:

(a) For local health policy makers and patients: The results of this study would improve the quality and patient outcomes of MRI services to the satisfaction of the patient as an external customer and the referrer as an internal customer.

(b) For Maltese MRI radiographers: The study has implications for the development of a local MRI competence profile, mandatory registration and CPD. It will support MRI radiographers in decisions regarding career paths.

(c) For the educational institutions: The results of the study are crucial to radiography educators for determining curriculum content.

1.8 Theoretical conceptual frameworks, philosophical perspectives and core values guiding this study

(a) Curriculum development: The general theoretical conceptual framework guiding the study was curricular development theory for professional education. Curriculum development, is a deliberate process of devising, planning, and selecting the content, methods of delivery, learner assessment and programme evaluation that would constitute an organized learning endeavour (Ornstein & Hunkin, 2009; Satava & Gallagher, 2015). Two curriculum development frameworks were used by the researcher in this study. The first framework by the Academic Development Unit at KU Leuven, Belgium, developed a generic scheme that can be used as a road map by all stakeholders (lecturing staff, students, representatives of the discipline and employers) involved in curriculum development (Huyghe et al., 2013). The second framework by an Australian Research Group provides a conceptual framework for curriculum development specifically in health professional education based on a renewal of inter-professional education and the linking of health curriculum to the larger political, social and economic issues (Lee et al., 2013).

(b) Research philosophy: Creswell (2009) provides a helpful discussion on the various philosophical perspectives which influence the methodological approach required by a researcher to conduct a research study. Four philosophical stances are identified: post-positivism, social constructivism, advocacy/participatory and pragmatism. The research philosophy of this project is founded on social-constructivism and pragmatism.

Social constructivists hold that knowledge is constructed by individuals with subjective meanings of experiences which are varied and multiple. In this situation, the researcher seeks to establish and look at the complexity of views rather than narrowing meanings into a minimal number of categories as in the case of post-positivism. The participants may be asked broad and general questions so that they may construct the meaning of a situation, typically forged in discussions or interactions with other persons, methods are qualitative. The researcher listens carefully to what people say or do and also focuses on the contexts in which people live or work. In such cases knowledge is social, arises from interaction with others and established *through levels of agreement and consensus*.

Pragmatism as a philosophical stance arises out of actions, situations and consequences rather than antecedent conditions. The research focuses on what works and solutions to defined problems or issues (Patton, 2001). Instead of focusing on methods, researchers emphasize the research problem and use all approaches available to understand and resolve the problem. As a result, it is a philosophical underpinning for mixed qualitative/quantitative approaches. Individual researchers have freedom of choice regarding approaches, methods, techniques and procedures of inquiry that best meet the objectives and best understanding of the research problem.

In this study, the general research strategy is one where the perceptions and thoughts of multi-stakeholder groups of experts in MRI are explored and critically assessed to address the practical task of developing consensus over an inventory of MRI biomedical imaging physics learning outcomes. The overall strategy of the study is therefore construction and validation through consensus. Therefore, the philosophical stance was mostly social-constructivist with pragmatist components.

(c) Practitioner research: Another research paradigm guiding the study is practitioner research, which is research carried out by practitioners with the aim of improving their own practice and the general practice of their profession. The author of the study is a member of the radiography profession having practised for eighteen years in MRI and involved in the delivery of continuous professional development to MRI radiographers. The idea for the project arose from recognition by the author, that the profession is at cross-roads regarding the registration of MRI radiographers in the specialist register in Malta. The development of a competence profile and associated learning outcomes would be a good start to set up a robust MRI qualification and certification based on the European qualification framework. The need for the study was presented to the directorate of allied health care professions.

The study was also guided by the following core values:

Service Quality: consistently perform to improve the quality and safety of care.

Client satisfaction: commitment in providing a positive experience to patients and referrers

Improving Working life: providing a supportive and encouraging working environment, increasing employee satisfaction and loyalty and adopting an inter-professional team approach.

Finance: demonstrates fiscal responsibility and accountability through an efficient service operation.

Growth: commitment to continued development, innovation and organizational enhancement

Collaboration: continuously meeting the needs of our customers by actively collaborating with other professions and organizations.

1.9 Research design

The research approach was mixed, including both qualitative and quantitative aspects mostly in a sequential design (Creswell, 2009).

The first objective involved an investigation on the forecasted MRI services that would be needed in Malta by the year 2020. This was conducted in two parts: a set of qualitative semi-structured interviews with a multi-stakeholder expert group of radiologists, referrers, radiographers, patient representatives, medical physicist, policy makers and manufacturers of imaging equipment were used to develop an initial version of the 2020 service portfolio which was subsequently validated quantitatively using an online modified Delphi study.

The second objective focused on the optimization of the MRI care pathway and involved qualitative-quantitative work using a nominal group technique with a second multi-stakeholder expert group.

The third objective involved using a cross-sectional qualitative documentary survey of competence profiles and qualification and certification frameworks in the major English-speaking countries. The findings were confirmed by triangulation with information solicited through a web-based questionnaire amongst a select group of MRI expert radiographers from the countries concerned.

The fourth objective used the results of objectives 1 to 3 in order to develop a competence profile for MRI radiographers in Malta. Qualitative analysis of documents (competence profiles identified in objective 3, text-books, research articles) and subject matter experts provided input to the development of the competence profile A quantitative Delphi study with radiologists, radiographers and medical physicists was subsequently carried out to validate the competence profile.

The fifth objective involved the development of the inventory of MRI physics learning outcomes (knowledge and skills) required of MRI radiographers to be able to deliver the competence profile developed in objective 4. Qualitative analysis of documents (course syllabi, text-books, research articles) and subject matter experts provided advice for the development of the inventory which was then validated amongst an international expert group including radiologists, radiographers, medical physicists and radiography educators using a quantitative survey.

1.10 Selection of participants

This study was bounded by the specific area of expert practice in MRI. The primary criteria for choice of participants was therefore qualification and experience in MRI. Due to the nature of the study, participants were selected using a purposive sampling technique to ensure that the final results reflected the opinions of multi-stakeholder expert groups and as required by the particular nature of each particular research objective of the study.

1.11 Literature databases

Literature from various electronic databases (Web of Science, SCOPUS, Medline, CINAHL and EMBASE) found in the University of Malta library portal were searched using the terms MRI physics for radiographers, learning outcomes for radiographers, competence, competence profile, European Qualification Framework, curriculum development, clinical care pathways, and curriculum development theory. Terms were used alone and in combination.

Reference lists of published articles were used to identify more articles. This resulted in the retrieval of a large number of publications (circa 700). This phase was invaluable to the researcher in order to obtain a overall picture of the field of curriculum design, as well as to identify key elements of learning outcomes as defined in terms of knowledge, skills and competences, radiography education and MRI physics for radiographers. Due to the large number of abstracts involved , relevant sections of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology were used to evaluate articles for relevance (Moher et al., 2009; Moher et al., 2015). The evaluation was based on a three-point scale of whether:

1. The article could definitely inform the research context and objectives.
2. The article could possibly inform the research context and objectives, or
3. The article was irrelevant to the scope of the research.

Duplicates, and articles not written in the English language, were eliminated. The majority of the articles were written by authors from the UK, US, a few from other miscellaneous European countries, and some from Australia, Canada and New Zealand. The initial search was conducted in September 2011 and repeated at regular intervals up to April 2017 since MRI technology and radiography education are continuously developing endeavours with new articles being constantly published.

Updates on the latest developments in the fields of MRI education and MRI physics for radiographers were also ensured through regular attendance at congresses, conferences and workshops.

1.12 Ethical responsibilities

Ethical approval for each objective was sought and obtained from the University of Malta Research Ethics Committee (UREC) to conduct the study.

The ethical approval through UREC ensured that details of informed consent, anonymity and confidentiality, rights to withdrawal, storage of data, dissemination of results and participant information were appropriately addressed. Written information sheets were given to all participants.

Informed consent from all participants was gained. To ensure confidentiality, interviews were carried out in a safe and private environment chosen by the participants themselves and all participants' responses were anonymised. As per standard practice, participants were advised that they were free to withdraw from the study at any time. The participant information sheets and informed consent sheets used in the various objectives of the study can be found in Appendix A.

1.13 The Researcher: location in research context and possible impact on study

As of March 2011, the researcher holds the position of professional lead in Diagnostic Radiography at the Ministry for Health. Before this appointment he occupied the post of senior principal radiographer and team leader in MRI. He now reports directly to the chief executive officer at Mater Dei hospital and oversees the work of radiography staff in all public imaging facilities in Malta and Gozo. The professional lead also chairs the Medical Imaging Department management and strategic team contributing to strategic decisions across all public medical imaging services.

In 2007, he was appointed as policy board member for the SMRT / ISMRM and appointed regional chair for Europe. In 2009 the researcher set up the Malta Magnetic Resonance Radiography Group (MMRRG) as a community of practice to organise educational courses and seminars. As lead radiographer in MRI, the researcher was directly involved in the board of studies of several Radiography courses at the Faculty of Health Sciences and the curriculum development for the Master's degree programme in MRI which started in October 2010. The researcher was invited speaker in several international conferences such as the European Congress of Radiology.

A reader from the positivist philosophical perspective would raise the possibility of bias arising from the researcher being the architect of MRI services in the public hospitals and himself an MRI radiographer. However, on the other hand, from the interpretative perspective the researcher is well placed to offer insider insights that would not be possible from those on the outside (Yanow & Schwartz-Shea, 2015). Within this approach insider knowledge actually benefits the analysis and the conclusions drawn from the results (Harvard Graduation School of Education, 2008).

To reduce bias the researcher adopted a social-constructivist epistemology where the results are derived from the perceptions and collaborative thoughts of a group of MRI stakeholders. This epistemological perspective was adopted by the researcher to not only ensure that the WHO recommendation regarding the involvement of stakeholders in curriculum design was respected but also to ensure that possible personal bias as an MRI radiographer was minimised. Personal body language was carefully controlled during interviews to inadvertently avoid expressing personal reactions to participants' responses. Language used in questions was analyzed independently of the researcher to avoid leading language. Triangulation was used when possible. A reflective diary was also kept and used to reflect in an ongoing manner on possible personal biases.

1.14 Advisory Board of Experts

A multi-disciplinary Advisory Board of Experts (ABoE) consisting of an MR radiographer, an MR radiologist and an MR medical physicist of repute was set up at the beginning of the project to offer guidance. Orientation of such subject matter experts (SME) to the purpose of the study is fundamental to achieve the desired result (Grant & Davis, 1997). The experts were appointed advisors to the researcher and were involved in the purpose of the project, the nature of the information sought, the role they were expected to play, the guidance they were expected to offer during the study and were requested to pay special attention to the possibility of researcher bias. Moreover, the ABoE also assisted in the validation of tools used for this study, and gave feedback on all published articles and conference presentations. The experts all had subject matter expertise in MRI and interest in the whole area of the development of education in MRI, medical physics and radiology. All had more than 10 years of experience in the field including several publications.

The MR Radiographer is a senior lecturer and postgraduate course leader at the Faculty of Health & Social Care and Education at a prominent UK university, where she runs a postgraduate Master's degree in MRI. She also organizes MRI courses and has taught and examined in many other national and international courses including undergraduate and postgraduate programmes. Her interests are focused on developing further MR education (including physics aspects of MRI for radiographers) using various modes of delivery including online applications.

The MR medical physicist specialized in Magnetic Resonance Imaging and completed his PhD on the topic of Spatial Distortion in MRI with Application to Stereotactic Neurosurgery. His research career developed at a UK university and later in an American University. His interests are focused on the application of advanced MRI techniques to translational research, both clinically oriented and in the field of neurosciences. His current collaborative projects involve characterization of complex plaque in the head and neck, perfusion and diffusion imaging for the assessment of brain tumours both in adults and children, and investigation of patients with Multiple Sclerosis on 7T MRI.

The MR Radiologist is a consultant at Mater Dei Hospital, Malta. He was instrumental in the setting up of the radiology postgraduate education system in Malta and is now the national post-graduate training coordinator for radiology. He was one of the first radiologists in Europe to acquire the European Diploma in Radiology (March 2001). Since January 2017 he became the President of the Malta Association of Radiologists and Nuclear Medicine Physicians.

The ongoing advice received throughout the research study by all the members of the ABoE was invaluable. The names of the Advisory Board of Experts' can be found in the 'Acknowledgements' section.

1.15 Overview of the rest of the dissertation

The rest of the report is structured as follows:

Chapter two provides a critical review of the literature including general models for curriculum development for the healthcare professions, the Bologna process culminating in the EQF, curriculum content expressed as learning outcomes, the concept of a competence profile, curriculum development for MRI radiographers, biomedical physics learning outcomes for radiographers including MRI radiographers and learning outcome inventory development and validation in radiography and other health care professions. Chapters three to seven present the background, purpose, methodology, results and discussion for each objective. Chapter eight presents conclusions from the study, reflections on the study, limitations of the study and recommendations for future research.

A substantial part of the text of the dissertation is based on the published papers listed in the initial pages under the heading "Publications and presentations arising directly from or associated with the study".

Chapter 2: Literature review

2.1 Introduction

The purpose of healthcare education is to produce professionals who will "deliver patient-centred care as members of an interdisciplinary team, emphasizing evidence-based practice, quality improvement approaches and informatics" (Greiner & Knebel, 2003). In meeting this aim, medical, nursing, pharmacy, and other health professions educational institutions are now developing their curricula focusing primarily on the articulation of learning outcomes expressed in terms of the competences and the associated knowledge and skills that the health professional would require in order to work effectively, safely and efficiently whilst using the least resources.

This chapter presents a review of the literature in relation to the development of learning outcomes with a specific emphasis on the health care professions and in particular radiography and MRI radiographers. It first presents two models for curriculum development in health professional education as an organising framework to the development of learning outcomes. The factors impacting the development of learning outcomes such as the Bologna process in Europe (culminating in the definitions of learning outcomes in the EQF), the variable use of the term 'competence' and competence profiles are discussed. This is followed by a critical analysis of the literature concerning competence profiles and learning outcomes for radiographers and MRI radiographers and including biomedical imaging physics learning outcomes. The chapter ends with a review of approaches to the development of competence profiles and learning outcomes adopted by curriculum developers in the healthcare professions with a focus on consensus methods.

2.2 Curriculum development models for the healthcare professions

Curriculum development refers to a collection of procedures that results in curriculum change. It should be systematic and research based and requires thoughtful action (Ornstein & Hunkin, 2009; O'Neill, 2010). Models of curriculum development fall within two complementary classes: 'Product Models' and 'Process Models'. The product approach is based on Tyler's (Tyler, 1949) rather systematic curricula planning approach which as a minimum would include the means of deciding what should be learned (i.e., content expressed as learning outcomes), how this content should be delivered to the learners, how the assessment of the learning should be carried out and how the curriculum would be evaluated. Stenhouse (1975) on the other hand, advocated for a process approach in which he proposed to select content, develop teaching strategies (including sequencing of the learning experiences) and finally assessment of students with an emphasis on post-positivistic approaches. Thus, the process model approach was designed to be not an outline to be followed for the development of curricula but to consider curriculum suggestions as proposals (i.e., hypotheses) to be tested empirically. Alternatively, Ornstein and Hunkins (2004) classify curriculum development models as having 'Technical-Scientific' or 'Non-Technical' approaches. The Technical-Scientific approach emphasizes efficiency and effectiveness in delivering education. The Non-Technical, in contrast, has been described as subjective, personal, aesthetic and focusing on the learner.

Most attempts to design healthcare education curricula including the development of learning outcomes remain fundamentally based on the product approach model. Harden's influential 'ten questions to ask when planning a course or curriculum' (Harden, 1986)) (see Table 2.1) as well as Kern's (Kern, 1998; Thomas et al., 2015) six step approach' (see Table 2.2) fall into this category. Both approaches underpin the importance in identifying learning needs at both the general and specific levels to guide curriculum development, hence assessing the needs of a specific group of healthcare professionals practising in a particular context (e.g., MRI radiographers in Malta) because this could be different from the needs of group of healthcare professionals practising in a general setting (e.g., Radiography in Europe).

1. What are the needs in relation to the product of the training programme?
2. What are the aims and objectives?
3. What content should be included?
4. How should the content be organized?
5. What educational strategies should be adopted?
6. What teaching methods should be used?
7. How should assessment be carried out?
8. How should details of curriculum be communicated?
9. What educational environment or climate should be fostered?
10. How should the process be managed?

Table 2. 1 - Harden's 10 steps to curriculum development

1. Step 1. Problem identification and general needs assessment
2. Step2. Targeted needs assessment
3. Step 3. Goals and objectives
4. Step 4. Educational strategies
5. Step 5. Implementation

6. Step 6. Evaluation and feedback

Table 2.2 - Kern's six step approach

Ho and colleagues (2009) presented an outcomes-based approach towards curriculum development whereby desirable learning outcomes are identified and considered in the formulation of plans. The approach is similar to Kern's six-step model but with the addition of a feedback mechanism using surveys and focus groups reviews; this feedback mechanism leading to cyclic refinement of the curriculum was highlighted as an important step to achieving a quality curriculum.

However, many curriculum development projects following the above frameworks in healthcare professional education often do not go far enough. A typical application is that of Wong (2006) who applied a Tylerian model and proposed a cyclical framework to develop a postgraduate curriculum for anaesthetists. Identification of learning outcomes started with a needs assessment from all identified stakeholders with input from the learners, teachers, administrators and support staff. However, Wong focussed only on learning needs from the perspective of the students and learners, teachers, administrators and support staff and there was little, if any, attempt to forecast the future needs of the community that the professionals would eventually serve. In fact, the studies did not adopt a sufficiently wide multistakeholder collaboration - she did not include the whole range of stakeholders (e.g., she did not include other professions, equipment vendors, biomedical engineers, patient representatives, etc), although she did emphasize that the curriculum development committee should make use of group consensus methods such as the Delphi and Nominal Group Techniques in setting curriculum goals and objectives. Such approaches, rarely consider the difficulties that healthcare managers face to release staff to attend CPD courses or the decision making required to determine future learning needs or workplace practices that should actually shape the curriculum. In fact, far from being interpreted merely as the production of a set of course documents, a broader view of curriculum development in health care should focus on the design and capabilities of current and future health services specific to the local context and health care needs, which would in turn be influenced by the social, political and economic factors surrounding contemporary health professional practice. Such factors include quality, safety and access to healthcare, the changing role of health consumers and communities, specialisation and the primary healthcare role leading towards greater collaboration among health professions, and finally the move to global healthcare (Lee et al., 2013; Crisp & Chen 2014). These issues are often not considered systematically during the curriculum design process. As a result, the curriculum planning process is carried out with little attention to policy and workforce dynamics (Lee et al., 2013).

A literature search for contemporary conceptual curriculum development frameworks schemes which were validated through a formal research process, based on a multistakeholder collaboration and linking healthcare education to health policy, workforce dynamics and current and future professional practices yielded only two curriculum development frameworks one of which was specifically for health care professions (Lee et al., 2013) and the other for higher education in general (Huyghe et al., 2013). In addition to the aforementioned characteristics these two schemes were also based on adult learning theories, aimed at curriculum development as opposed to individual courses and generic enough to apply to all healthcare professions. Following the Bologna declaration in 1999, (Bologna Working Group, 2005; Keeling, 2006) the Academic Development Unit at KU Leuven, Belgium, developed a scheme aligned with the assumed learning outcomes and that can be used as a road map by all stakeholders (teaching staff, students, managers, representatives of the discipline and labour market) involved in curriculum development (Huyghe et al., 2013). The framework is presented as a dynamic environment that is continuously developing according to environmental demands and contextual changes which incidentally is also a common scenario in healthcare. Through a consensus approach the Leuven group, identified 11 curriculum development elements which were grouped into three areas:

1. the need for an external advisory board representing the discipline, the research community, the labour market (via alumni) and society,
2. the planned curriculum representing the educational philosophy, the positioning of the curriculum and the learning outcomes, and
3. the aligned or coherent curriculum representing structure and sequence and aligning learning, teaching and assessment strategies (aligned here meaning tuned to the education philosophy).

These three areas are interlinked by four quality circles (Figure 2.1) representing

a. the expectations of the influencing stakeholders including labour market and society,
b. the development and implementation of curriculum through learning outcomes, learning opportunities and assessment,
c. the alignment of the curriculum in terms of the number of courses which are ordered in a certain sequence and structure
d. the instructional design of the course here meaning learning objectives, learning activities, student characteristics, evaluation strategies, the learning environment and context.

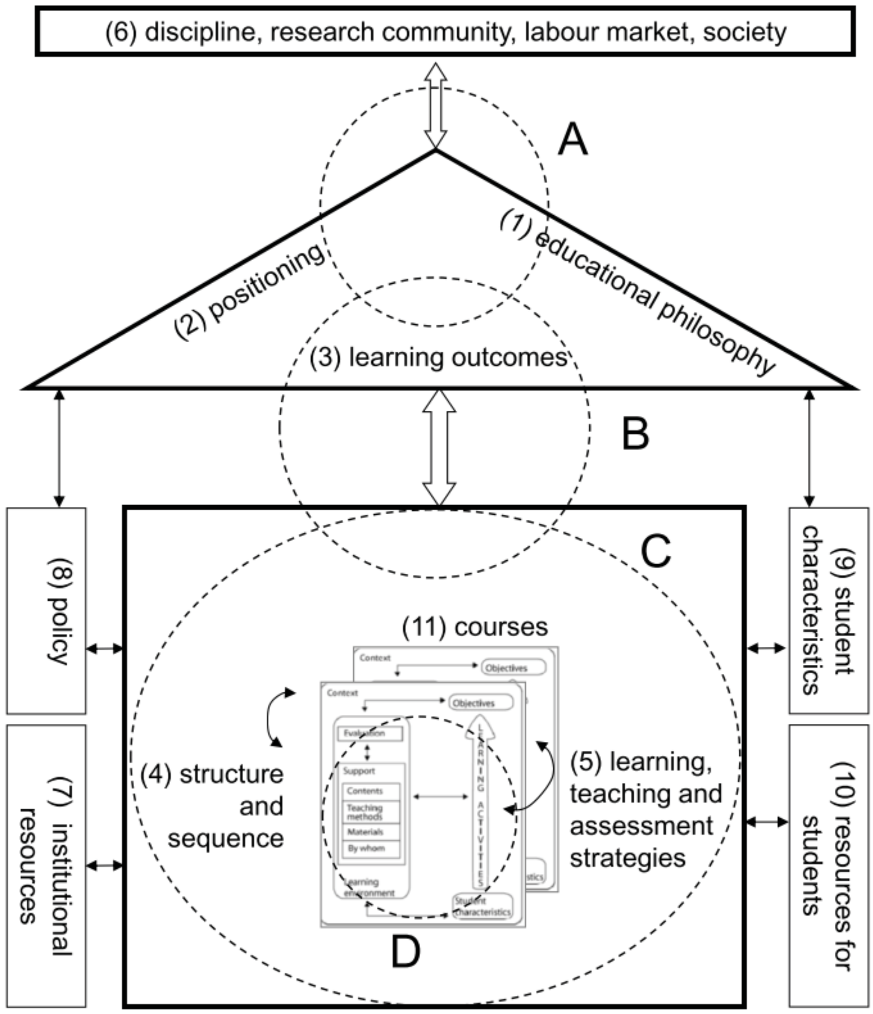


Figure 2.1 – Conceptual scheme for curriculum development by Belgian Group (Huyghe et al., 2013).

The recommendations of the Leuven group included a revision of the existing learning outcomes by consulting alumni, labour market, research community, students and faculty and mapping the new learning outcomes against the existing courses of the program. However, although the participants in the study found the framework useful it lacked detailed information and a roadmap of how to implement it.

Spearheaded by a review and renewal of inter-professional education an Australian research group (Lee et al., 2013) developed a conceptual framework for curriculum development in healthcare education. The four-dimensional framework connects the curriculum for which it aims to prepare graduates directly to the broader political, social and economic issues surrounding that healthcare profession while at the same time acknowledging the cultural forces that may often underpin these issues. The first and second dimensions are the most relevant to this project.

The first dimension seeks to connect the healthcare professionals practice needs to changing workplace demands by forecasting future healthcare services and practice. As a result, the curriculum is shaped by:

1. reforms in health and educational policies,
2. requirements of registration bodies, and professional bodies
3. public and private future service portfolios

The second dimension leads to the group proposing that professional practice should be learned on the job, through practising and systematic critical reflection rather than being just the application of theoretical knowledge gained during traditional modes of study (Barnett & Coate, 2004).

The above two frameworks agree that curriculum development should address future healthcare needs and involve all the stakeholders. However, neither of the frameworks offers a prescriptive set of steps to be followed by curriculum developers. Unfortunately, little attention is given by the two groups on the development of learning outcomes proper. Rather, both groups offer a common 'language' or a mind map to assist educators who are developing, reviewing or reengineering health professional courses so that graduates can receive the most comprehensive preparation for the complexities of the present and future health workplace.

This research adopts the multi-stake holder collaboration approach as proposed by these frameworks to offer a prescriptive methodology for curriculum developers to develop an inventory of learning outcomes. Posner (2004) emphasizes that curriculum development involves technical decisions about relevancy of learning outcomes and suggests that the best people to make such technical decisions are the people with the most knowledge relevant to the profession or subject. This study therefore employs a multi-stakeholder approach as no single stakeholder can be expected to detect all facets of a service. All stakeholders must be given the opportunity to put forward their thoughts and concerns in a non-threatening environment so as to facilitate the development of strategies that will encourage the exchange of ideas and decision making so that all facets can be explored. The WHO recommends that curriculum development in the health care professions should be carried out through intersectoral collaboration involving Ministries of Health, Ministries of Education, public and private training institutions, and health professional organizations (World Health Organization, 2006). Using this approach this research will therefore focus directly on the future health needs of the local community, health policies regarding MRI accessibility and its implications for educating a health workforce capable of practising in contemporary models of care (Lee et al., 2013). This study will develop a set of biomedical imaging physics learning outcomes to support the competence profile required for the safe, effective and efficient running of a future MRI service portfolio in Malta as determined by multidisciplinary stakeholder groups.

2.3 The Bologna Process, the European Qualifications Framework (EQF) and learning outcomes

The beginnings

Lifelong learning and the mobility of students and workers was always high on the European agenda and in 1987, the European Union established the Erasmus programme. This was later incorporated into the Socrates programme established in 1994. The lifelong learning concept and mobility of students and workers across Europe led to the introduction of a new initiative - the accumulation and transfer of learning credits

In the meantime, higher education systems, all over Europe were struggling to modernize in response to a changing working environment. Shared problems called for shared solutions and this led to the Bologna process which developed into an educational reform committing signatory countries to 'harmonising the architecture of the European Higher Education system'.

The European Higher Education Area Qualifications Framework (QF-EHEA)

In Bergen in 2005 the European Higher Education Area (EHEA) Framework was adopted. This objective concerned all countries of the Bologna Process which now include 50 European nations and they concluded that the structuring of higher educational qualifications should be based on three levels called 'cycles' (1st cycle Bachelor, 2nd cycle Masters and 3rd cycle Doctorate). This led to a university driven project called 'Tuning Educational Structures in Europe' programme which aimed to offer a concrete approach to implementing the Bologna agreement at the HE level for subject areas such as Radiography. Tuning requires educational institutions to promote student-centred curriculum development based on agreed cycle learning outcomes. Although learning outcomes are formulated by staff these should be designed from the point of view of the student. It is indeed this feature that distinguishes learning outcomes from conventional teaching objectives which were written from the point of view of the teaching staff. Learning outcomes are to be acquired by the student and their acquisition by the student facilitated by the academic/clinical staff. The QF-EHEA recognised only one type of learning outcome which is 'competence' and explains why in Tuning documents 'learning outcomes' and 'competences' were often seen as synonymous. Once again it is noted that these competences were to be determined through the collaboration of all stakeholders. Competence was defined by Tuning as "a dynamic concept that integrates knowledge, skills, abilities, values and attitudes, the development of which enables the learner to perform effectively, to be able to recognise and respond to change and to treat service users appropriately". This definition seems to indicate that the project leaders were aiming at an integrated product and process approach towards curricular design. The Tuning leaders also proposed that competences be classified in two categories namely Generic and Subject Specific. Generic competences are defined by Tuning as those skills which are transferable across professions and which are particularly important to employability and citizenship whilst subject specific competences are specific to each particular profession. This project considers Subject Specific Competences for MRI radiographers.

The European Qualifications Framework (EQF)

In 2008, the European Commission launched the European Qualifications Framework for lifelong learning. Building on the successful policy goals of the EHEA, such as the consistency in the design of qualifications it takes the issue of qualification frameworks even further. The EQF acts as a guideline for the Member States and for other European and non-European countries on which to model their national qualifications framework. The EQF is not a one-fits-all framework; it must be interpreted according to national priorities agreed upon between policy-makers, training providers and key stakeholders.

It is also an integrated framework to bridge the gap between VET and HE because permeability between VET and HE enhances lifelong learning. This is achieved through flexible learning pathways including all forms of learning (formal, informal and non-formal) with the focus being on the individual learner with no age restrictions. The ascending levels of difficulty of the EQF provide a benchmark for the validation of formal, informal and non-formal learning. This factor encourages early school leavers to re-train themselves and hence motivates the low skilled and promotes an inclusive society.

The key prerequisites for National Qualifications Frameworks include learning outcomes based qualifications and educational levels. Before enrolling into educational institutions (whether HE or VET) learners would have a clear picture of what the course is all about and to what learning outcomes it leads to, therefore learning outcomes-referenced qualifications can also be considered as a tool for career guidance. Learners in the work place are encouraged to update previously acquired learning outcomes and develop new skills to keep pace with change.

Learning outcomes should not be designed solely by policy makers, but should be shaped by the stakeholders' contribution depending on the qualification(s) reviewed. Stakeholders such as social partners, education and training providers, sectoral representatives, learners and civil society are now the key actors who define learning outcomes tailor made for society's needs. This shift is considered "as an opportunity to tailor education and training to individual needs, improve links to the labour market and improve the way non- formally and informally acquired learning outcomes are recognised.”

The EQF definition of learning outcomes and standardisation of the concept of competence in Europe

The EQF distinguishes between three types of learning outcomes namely knowledge, skill and competence (KSC) learning outcomes. In the EQF, knowledge is defined as “The outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual”; skill is defined as “the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments)”; competence is defined as “the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the EQF, competence is described in terms of *responsibility and autonomy*”.

The development of learning outcomes in terms of knowledge, skills and competences as defined in the EQF is now being used increasingly in Europe. The document MEDRAPET (Olsen, 2012; European Commission, 2014) and the European Guidelines on the Medical Physics Expert are two examples whereby the major stakeholders collaborated to develop inventories of learning outcomes. MEDRAPET was an EC-funded project conducted between December 2010 and March 2013 with the overall aim to improve implementation of the Medical Exposure Directive provisions related to radiation protection education and training of medical professionals in the EU Member States. The project was awarded to a consortium of European organizations who through collaboration first carried out a survey amongst relevant stakeholders e.g., Radiation Protection Boards, professional bodies and educational institutions to assess the level of radiation protection training in Europe. An overview of the results from the survey of key stakeholders clearly showed an urgent need to build a bridge between Radiation Protection Authorities, Professional Societies and Educational Institutions, in order to achieve the goals of European directive 2013/59/EURATOM.

Following the survey, the group met to develop the inventory of learning outcomes which includes a common core of learning outcomes to be acquired by all professions at the entry level to the professions and profession specific learning outcomes for referrers, physicians directly involved with radiation protection, dentists/dental surgeons, radiographers, medical physicists, nurses and biomedical engineers. The learning outcomes are all in the knowledge, skill and competence format. Similarly, the European Commission contracted a consortium of stakeholders to develop an inventory of learning outcomes for Medical Physics Experts (MPE). In this project, the final inventory included generic learning outcomes, core learning outcomes for all medical physics experts and learning outcomes specific for MPE specializing in diagnostic and interventional radiology, nuclear medicine and radiotherapy. The inventory is also in the KSC format, but although the methodology used is not described in the actual guidelines, personal communication (C. Caruana, personal communication, December 17, 2016) confirms that a collaborative method was adopted using surveys to get information about medical physics education, role of the MPE and the survey data used to develop the inventory. The inventory was sent to representatives of all stakeholders including ESR, EFRS and IAEA for their feedback. In both cases, the inventories were developed to promote harmonisation across Europe. Both are guidelines as the EC cannot mandate educational curricula. This study follows this curriculum content development trend and uses the EQF definitions of knowledge, skills and competences.

Although the definitions of knowledge and skill have been quite consistent in the literature the definition of competence has not always been so and has been mired by ambiguity(White, 1959; Castillo et al., 2011). The concept of competence is derived from the Latin competence, which means capable or qualified. White (1959)) is credited with having introduced the term to describe those personality characteristics associated with superior performance and high motivation. McClelland (McClelland, 1973) followed this approach and developed tests to predict competence as opposed to intelligence. Since then several definitions and approaches to the concept of competence have been proposed and there has been a general lack of consensus over the meaning and use of the term. To add to the ambiguity, articles in the educational literature present two spellings of the word, namely, 'competence' and 'competency' offering the same meaning to each with their respective plurals 'competences' and 'competencies' readily interchangeable. The first form of the word is in general used in the EHEA and Tuning documentation and the second in documentation from the US, Canada, Australia and New Zealand. Some authors and organisations from the professional literature propose a distinction between 'competence' and 'competency'. For example, the Chartered Institute of Personnel and Development (UK) offers the following distinction: "Competency is now generally defined as the behaviours that employees must have, or must acquire, to input into a situation in order to achieve high levels of performance, while competence relates to a system of minimum standards or is demonstrated by performance and outputs". Woodruffe (1993) provides a similar distinction: "A competency is the set of behaviour patterns that the incumbent needs to bring to a position in order to perform its tasks and functions with competence". The inference here is that 'competency' is a level of behavioural excellence to aspire to, whilst 'competence' is simply a statement of minimum observable performance which is considered acceptable. Rowe (2013) makes a distinction between behaviours that are cognitively based and those that reflect personal values. In the cognitive category

Rowe includes problem solving, decision making, strategic thinking, and working with information whilst personal values include honesty, integrity, commitment and courage. Delamere le Deist and Winterton (2005) suggested an overarching framework in which cognitive, functional, social and metacompetences are combined and viewed in holistic terms so that a combination of competences is something more than the sum of the individual competences. In Europe, the various definitions of competence found in the research literature and other educational documents from UK, France and Germany were used by the Bologna Working Group in Europe to suggest that competence includes:

(i) cognitive competence involving the use of theory and concepts, as well as informal tacit knowledge gained experientially,

(ii) functional competence (skills or know-how) referring to those activities that a person should be able to do when functioning in a given area of work, learning or social activity,

(iii) personal competence involving knowing how to conduct oneself in a specific situation, and

(iv) ethical competence involving the possession of certain personal and professional values.

In a later document leading to the EQF recommendations, the terminology was simplified: 'cognitive competence' was termed 'knowledge', functional competence was termed 'skills' and personal and ethical competences were combined into a single category termed 'wider competences'. The wider competences included autonomy and responsibility, learning competence, communication and social competence and professional and vocational competence. However, in the final EQF recommendations the term 'wider competence' was dropped in favour of the simpler term 'competence'. The definition of competence in the EQF places emphasis on 'responsibility and 'autonomy' which reflects the importance of these concepts in work and study situations in which practitioners assume responsibility in an autonomous manner for their professional practice and also for their own learning. For all intents and purposes following the EQF the word 'competence' has become synonymous with 'responsibility'. A full discussion can be found in the article by Castillo et al (2011) - The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level. Radiography, 17(3), 230-234.

2.4 The concept of competence profile

A competence profile is defined as a list of key responsibilities for a given class of health care professionals exercising their profession in a particular context. Competence identification, modelling and profiling have been introduced in many fields to describe key characteristics of (successful) performers in a particular job category. In particular, competence profiles are mainly used to update and improve the quality of (vocational) education and training that prepares people to work in a given sector, and the quality of human resource development within organisations, i.e., via in-service and on-the-job training (Rothwell & Lindholm, 1999; Vazirani, 2010). Competence profiles are also used by educators and policymakers to clarify and link workplace requirements to educational programmes and curricula (Rothwell & Lindholm, 1999; Vazirani, 2010). Training and development professionals use competence profiles to clarify organisation-specific competences with a view in mind towards improving performance and unifying individual capabilities with organisational competences (Vazirani, 2010)). A competence profile is a standardised description of competences necessary to function as a capable practitioner in a particular context.

Subject specific competence profiles are valuable to students, faculty, and employers. Students can use such profiles to form accurate perceptions, dispel misconceptions, and generate motivation to pursue a field of study. Faculty can use competence profiles to clarify practices in their disciplines, design appropriate educational materials and instruction, and link other disciplines to their own. Employers can use these competence profiles to communicate their expectations to educators and to guide professional development for employees.

Competence and competence-based education are terms becoming increasingly utilized both nationally and internationally (Mulder, 2001; Weigel et al., 2007; Sultana, 2009). In Malta, competence-based education started with vocational education training institutions and has now become a priority in designing and redesigning teaching and learning processes in higher education as well (Sultana, 2009).

Despite the advantages of competence profiles, concern has been raised on an over-reliance on standardisation of competences, because the power of competence profiles and associated competence-based education lies in its context-embeddedness. Usually, the reality of work is quite different from job descriptions and organisational regulations on paper (Biemans et al., 2004). Using overly standardised / broad competences is really missing the point, since every abstraction from actual practice makes them less applicable. Related to the problem of standardisation is the issue in forecasting techniques: competence profiles should also relate to service in the future, for which students are educated. However, many competence profiles only relate to current practice. Too strict a use of competence profiles leads to conservative training, instead of preparing students for innovative developments and for providing the future needs of society (Biemans et al., 2004). Hence, in the case of MRI radiographers an inventory of learning outcomes that is based on a competence profile that is based on a *forecasted future* service portfolio and on the *future envisaged optimised* patient care pathway would assist managers in developing context specific CPD programmes for future health care needs of patients.

2.5 Competence Profiles and learning outcome inventories for radiographers including MRI radiographers

The Higher Education Network for Radiography in Europe (HENRE) had developed an inventory of agreed learning outcomes for the first cycle of Radiography (diagnostic and therapy) education. These learning outcomes were not in the KSC format but in the former 'competence-only' format. Hence not all competence statements can be considered as responsibilities, and in fact many are actually knowledge/skills statements. Eventually in 2013 the European Federation of Radiography Societies published an inventory of learning outcomes for diagnostic radiographers at entry level (EQF level 6). The learning outcomes were developed by a small group of experts and discussed with the EFRS Board, EFRS general assembly and EFRS educational wing. This process did not include any surveys to determine current or forecasted competences upon which the competences, knowledge and skills were developed, nor was the opinion of employers, policy makers and other stakeholders sought. In contrast to the MEDRAPET learning outcomes for radiation protection which include clear concise statements of knowledge, skills and competences (also included as appendix in same EFRS document), the learning outcomes specific to Radiography are broad and lengthy worded statements at times with significant repetition. EFRS has not yet published any learning outcomes for the advanced imaging modalities such as CT, MRI, Ultrasound, Mammography and Interventional Radiography. Very importantly for this study, a literature search indicated that no agreed pan-European competence profile for MRI radiographers has yet been developed in Europe.

Radiography is considered an emergent profession and MRI is being considered as a sub-specialization. This is certainly the case of the major English-speaking countries Canada, United Kingdom, Australia, New Zealand and Ireland. In Canada, (specifically in Alberta) and United States there exists a primary pathway into the Magnetic Resonance profession. Canada and New Zealand have mandatory certification and registration based on national MRI-specific competence profiles. A similar trend has been followed in the US since January 2015. In Australia, the AIR offers a certification and registration pathway referenced to a national qualification framework and to a set of generic professional practices standards that may be applied to MRI. In the UK, Skills for Health has developed a national MRI competence profile (here called 'occupational standards') which cover key MRI activities. None of these competence profiles / standards are expressed in the knowledge, skills and competences format as required by the EQF. In Ireland, the radiographers' registration board has published a 'Guidelines on best practice' document which includes a list of professional responsibilities that are required by the MRI radiographer. Canada and the US each have an MRI competence profile, but unlike others developed by other professions such as nursing, these are not framed within a novice-to-expert continuum as suggested by Dreyfus (2004), Benner(1982) and

Yielder (2001). Having said this, the MRI specific competence profile in New Zealand was referenced to three distinctive ‘skill levels’. A detailed discussion of these competence profiles can be found in chapter 5.

A literature search for curriculum development in MRI yielded a handful of peer reviewed papers which focused mainly on independent learning and assessment (Gill, 2008) and role extension such as MRI reporting by Radiographers (Piper & Buscall, 2008; Young, 2008; Piper et al., 2010). An internet search yielded several exemplars of MRI curricular content from various schools for MRI, universities and colleges. Generally, these include a list of the modules with a description of the contents covered. *Again, in none of these is the curriculum content is expressed in the learning outcomes format of knowledge, skills and competences as required by the EQF.*

2.6 Biomedical imaging physics and MRI physics learning outcome inventories for radiographers

Radiography is perhaps the most physics based of all healthcare professions. Physics input is expected to swell as the number of imaging and therapeutic modalities used by both diagnostic and therapeutic radiographers increase in both number and complexity. Radiography is a blend of quantitative high technology and qualitative patient care. According to Price (2006) it has both ‘hard and soft perspectives’. Since Physics generally dominates the hard perspective then one would expect that physics should form a significant part of the radiography curriculum. In November 2008 HENRE published the Tuning document for Radiography in Europe which formed the basis for future curriculum development in radiography throughout Europe and included details of required curricular content for first cycle programmes (Caruana, 2009). The ‘Basic Sciences’ section (38% of the total ECTS assigned to the full programme) included ‘Physical Sciences’ in addition to the human biological and social sciences. The objective of physical science education within radiography would be to provide students with the “bio-medical physics competences underpinning the scientific, effective, safe and efficient use of medical devices used in medical imaging and/or radiation therapy” (Caruana, 2009). How to include these in an already congested curriculum will be a major issue (Akimoto, Caruana et al, 2009). Another issue that needs to be researched is how to include physics in integrated, competence-based radiography curricula.

A literature search for the development of biomedical physics curricular content resulted in only one study (Caruana & Plasek, 2006a). In their study, the authors made a systematic study of diagnostic radiography curricular and role development documentation and the physics component of diagnostic radiography curricula in Europe and developed a structured inventory of physics ‘elements-of-competence’ - a term used in the literature which at that time includes knowledge, skills and sub-competences – (C. Caruana, personal communication, May 2011) which underpin subject-specific competences in diagnostic radiography. It is to be noted that the inventory was developed in cooperation with HENRE and should form a good basis for a future European diagnostic radiography physics curriculum. The authors provide subject specific competences at both undergraduate and postgraduate level. The competences are generic and modality independent in nature but were applied to CT and not MR, USI and NM'.

In some universities in Europe, principles of diagnostic reporting and healthcare management are being expanded at the expense of the more technological aspects of radiography specifically physics (Akimoto et al., 2009) This could imply that entry level radiographers would not be in a position to cope with rapid changes in imaging device technology such as MRI and PET-MRI. Safety issues would increase. The most reported safety incidents in the UK database kept by the Medicines and Healthcare products Regulatory Agency (MHRA) are RF burns, most of which being 'contact' burns, while the second most reported events are projectile incidents. The most serious incidents are those where fatalities arise; the one death reported in the UK database was a pacemaker death, where the patient should not have been scanned in the first place. As the number of higher field systems is growing, the likelihood for projectile incidents, burns and implant incidents may rise. The authors suggested that an on-going programme of training rather than just simply a basic training in safety is warranted. This would play a critical part in reducing the number of MRI incidents (De Wilde et al., 2007). *Despite the importance of MRI physics education, a literature search yielded no research based biomedical physics learning outcome inventory for MRI radiographers.*

2.7 Overview of Consensus Techniques

From a social-constructivist philosophical perspective, the development and validation of competence profiles and learning outcomes utilizing multi-stakeholder decision making processes require consensus techniques such as the Delphi, nominal group technique or focus groups (Jones & Hunter, 1995; Kitzinger, 1995; Hutchings et al., 2006; Hsu & Sandford, 2007; Stalmeijer et al., 2014).

The Delphi technique

The Delphi technique is a widely used and accepted method for gathering data from participants within their domain of expertise. The technique is designed as a group communication process which aims to achieve a convergence of opinion on a specific real-world issue. The Delphi process has been used in various fields of study such as program planning in education, needs assessment in health, policy determination, and resource utilization to develop a full range of alternatives, explore or expose underlying assumptions, as well as correlate expert opinions on a topic spanning a wide range of disciplines. Initially, it appears that the epistemological basis for the

Delphi technique favours the post-positivist paradigm and this arises from the fact that the researcher assumes a position of an uninvolved observer. This is further supported by the use of a quantitative approach to data collection and the application of single statistical measure to evaluate the level of agreement and consensus. (Hanafin, 2004). On the other hand, the aim of employing a Delphi technique is to achieve consensus through the use of a series of questionnaires delivered using multiple iterations to collect data from a panel of experts. This process itself is concerned with opinions, ideas and words and is in keeping with social constructivism (Hanafin, 2004). A key advantage of the Delphi technique is the potential it holds to recognise and acknowledge the contribution of each participant and this collaboration (even though indirect in this case) is central to this study. Within this context it can be argued that the Delphi technique lies firmly within the social-constructivist approach because it allows the participants and researcher to change or develop their opinion based on feedback given by other experts. The most obvious advantage of Delphi is that of guaranteed anonymity in responding to individual questions and this is likely to encourage opinions that are free of excessive influences from others. Other advantages relate to the use of questionnaires (particularly online questionnaires) that have the capacity to enable a geographically dispersed group of experts to provide their understandings. It also has the potential to generate a large number of ideas. Respondents can complete the questionnaire at their leisure and this reduces time pressures and allows for more reflection and contemplation of response. This, in turn, may increase the number and quality of contributions and can decrease respondent burden by allowing participation at the participant's convenience. Anonymity in Delphi has been identified as a disadvantage because it may lead to a lack of accountability as a result of the fact that responses may not be traced back to the individual. In addition, it has been suggested that a consensus approach can lead to a diluted version of the best opinion and the result represents something in between (Sackman, 1975). Time frame to complete the questionnaires, possible low response rates and choice of statistical measurements should be carefully considered (Powell, 2003).

The NGT

The purpose of the Nominal Group Technique (NGT) is to generate information in response to an issue so that proposals can be prioritised through group discussion. While verbal communication is an essential feature that characterizes a "group", the reason that the term "Nominal" was used is that it describes group situations where non-verbal communication is a major part of the technique ('Silent' phase). Thus, the group is by definition only nominally a group. Although early researchers applied the term rigidly, and no verbal communication was permitted, recent NGT investigations allow both verbal and non-verbal stages albeit in a structured approach (Cross, 2005). Research has shown that by allowing the combination of verbal and non-verbal stages, the optimal benefit from a NGT investigation can be achieved. An objective of the NGT is that normative behaviour (which generally favours the performance of dominant or aggressive characters) will be controlled so that performance and outcome are maximized, while hidden agendas and negative group dynamics are suppressed. As a result, the NGT aims to draw out minority opinions and promote the tolerance of conflicting ideas (Cross, 2005). The Nominal Group Technique is a time efficient method of collecting data, as a session generally lasts between 1.5 and 2 hours, and participants are only required to attend a single session (Potter et al., 2004). Participants involved in the NGT take part in a highly structured face-to-face meeting involving six stages:

- Introduction and explanation about the purpose of the meeting
- Silent generation of ideas.
- Sharing ideas in round robin process until all ideas have been presented.
- Group discussion where participants are invited to seek verbal explanation or further details about any of the ideas that colleagues have produced that may not be clear to them.
- Voting and ranking in relation to the original question.
- Presentation of results which is immediate.

The NGT allows for efficient information exchange among experts, which is particularly important when participants offer unique points of view (Davies et al., 2011). Therefore, the epistemological basis for the nominal group technique is in keeping with social-constructivism. Selection bias and the definition of expertise are the most commonly cited flaws in consensus investigations generally. Other limitations include possible prohibitive costs involved in bringing group members together and the fact that cross-fertilization of ideas may be diminished due to lack of flexibility when NGT is overly structured (Delp et al., 1977). In addition, data analysis, in particular the qualitative aspect is a time-consuming process due to the volume of information collected (Lennon et al., 2012).

Focus groups

Focus groups involve a discussion within a (small) group of people. The group is led by a researcher/moderator/guide who stimulates active engagement of participants in a discussion and interaction between group members in order to gain depth in the exploration of the topic of discussion, and an understanding that this interaction is also a focus of the analysis. Focus groups as a consensus technique fit within a social-constructivist paradigm which views reality as socially negotiated and knowledge as a product of the social and co-constructed interaction between participants. The researcher engaging in focus groups is interested in participants' ideas, interpretations, feelings, actions and circumstances. In a focus group, the researcher as facilitator takes on a peripheral role moderating a group discussion between participants not between her/himself and the participants as what happens in interviews (Stalmeijer et al., 2014). Since focus groups are unstructured, facilitating group dynamics and moderating different responses is challenging and relies on strategic group configuration. In fact, issues of participants sampling and selection will prove to be crucial in relation to the form and quality of interaction. Individual respondents can react to and build on other group members' responses. This could also be a disadvantage if group dynamics include dominant individuals who may thwart full participation by all members thereby curtailing the richness of the data. As mentioned by Stalmeijer et al (2014) the best focus group participants are those who have personal or professional investment in the topic under examination either as a consumer, provider or policy maker. Focus group transcripts generate a large volume of qualitative data and requires more committed time to organize, interpret and analyse.

The advantages of focus groups include:

- gather information more quickly compared to Delphi Technique
- provide direct interaction with and observation of the respondents, both verbally and non-verbally
- obtain large and rich data in the respondents' own words

Comparison of the various methods

Table 2.3 shows the comparison between the three consensus techniques on a number of attributes.

Attribute	Delphi	NGT	Focus Group
Face-to-face meeting process	No	Yes	Yes
Generation of large number of ideas	Yes	Yes	No
Avoids losing focus	Yes	Yes	Yes

Encourages equal input from all participants	Yes	Yes	No
Highly structured process	Yes	Yes	No
Usually carried out in short time	No	Yes	Yes
Provision of immediate feedback	No	Yes	Yes
Quantitative data	Yes	Yes	No
Qualitative data	Yes	Yes	Yes

Table 2. 3 - Comparison between consensus techniques

This thesis will use the Delphi technique for Objectives 1 and 4 and the NGT technique for Objective 2.

2.8 Common measures of level of agreement and level of consensus found in literature.

Measures of level of agreement

Level of agreement or otherwise with a given statement (e.g., a competence statement) is invariably based on some form of Likert scale ranging from complete disagreement to complete agreement. Several sizes of Likert scales are found in the literature ranging from 5 to 19 levels of response categories (Cummins & Gullone, 2000a). The most important consideration is to include at least five response categories (Allen & Seaman, 2007). The ends of the scale often are increased to create a seven-point scale by adding 'very' or 'completely' to the respective top and bottom of the five-point scales. However, there are some potential difficulties in generating expanded scales, and one of these involves the tradition of using category names (Cummins & Gullone, 2000b). Using a very short scale means that there is too little discrimination between different levels of agreement. On the other hand, using very wide scales are less easy to use, take longer to fill and participants finds it difficult to discriminate beyond seven levels of response categories (Streiner et al., 2015). A compromise size is usually 6 and a typical scale is shown below:

Score	Level of Agreement with given statement
1	Completely disagree
2	Generally disagree

3	Slightly disagree
4	Slightly agree
5	Generally agree
6	Completely agree

Some authors use a Likert scale which includes a neutral 'neither agree nor disagree point' midway in the scale (Garland, 1991; Beaudin, 1999). Matell and Jacoby (1972) demonstrated that as the number of scale steps is increased, respondents' use of the mid-point category decreases. There is no absolute rule and depending on the needs of the particular research it may or may not be desirable to allow a neutral point (Streiner et al., 2015). In this research, the opinion of experts was being sought to arrive to a decision and therefore it was highly desirable to remove the mid-point. Since the distribution of the participant responses along the scale is not known and cannot be assumed to be Gaussian or even symmetric the value used to represent the level of agreement is usually the median and not the mean. Using the median would also offset any excessive influence of outliers (von der Gracht, 2012).

Measures of level of consensus

Several measures have been proposed as measures of dispersion about the median and hence levels of consensus e.g., interquartile range (von der Gracht, 2012). The Interquartile range (IQR) is the most commonly used (Sekaran & Bougie, 2016). An IQR of zero means that all responses are on the median and there is perfect consensus among the participants on the median value as the representative level of acceptance. A large IQR means that there is a wide dispersion about the median and hence a low consensus on the median value as the representative level of acceptance. An IQR of less than or equal to 1 on a Likert scale means that at least 50% of all opinions fall within 1 point off the median (De Vet et al., 2004; von der Gracht, 2012). The range of the IQR actually depends on the width of the scale. The more points there are on the scale, the larger the IQRs that can be expected. As a rule of thumb, an IQR of 1 or less is usually found to be a suitable consensus indicator for up to 7-point Likert scales (Rayens & Hahn, 2000; De Vet et al., 2004). In consensus studies involving several rounds e.g., Delphi studies, statements with IQRs below a predefined level e.g., 1.0 are not included into the next Delphi round, as consensus has been deemed to have been achieved.

Dichotomous studies

In the case of studies where the number of statements to be validated are large, Likert scales are rarely used because of the long time that would be required for participants to answer the questionnaire. In such cases the size of the level of agreement scale is reduced to two i.e., agree/ disagree. The level of consensus used in such cases is the percentage of participants demonstrating agreement. The cut-off point which is used as indicating sufficient consensus may be 50% and higher (majority), 67% or higher (2/3 majority) or even higher percentage values. The lower the cut-off point the more statements would be deemed desirable whilst too high a cut-off percentage means that a lot of statements would be lost.

Since the decision on cut-off points is often arbitrary it is recommended to state clearly the acceptable levels of agreement and consensus prior to data analysis to enhance the credibility of the results (Keeney et al., 2006). Issues in relation to measuring consensus are still debatable with no clear conclusions and thus, further research is required. Consequently, the decision on the desired level of consensus should be determined in consultation with the literature and with the objectives of the study in mind.

In this study and following consultation with the literature and the ABoE it was decided that for objectives using a Likert scale of size 6 with no neutral point would be used. The median would be used to measure the level of agreement and the interquartile range (IQR) the level of consensus. Cut-off points for desired level of agreement would be median ≥ 5 and IQR ≤ 1.0. In the case of a dichotomous scale the cut off will be 70% level of consensus.

2.9 Some consensus studies involving competence profile and learning outcome inventory development and validation

Unfortunately, the literature offers few exemplars of learning outcome development studies which include details of the consensus techniques used (Prøitz et al., 2017). Some exemplars are given to indicate the scope of such studies.

Since a significant amount of work dealing with learning outcomes and competences for medical education at undergraduate and post-graduate level already existed, Cumming and Ross (2007) on behalf of the Tuning project in medicine described how a set of learning outcomes was first generated from such previous work. For this study, the online questionnaires were used in order to obtain as wide a range of opinion as possible from academics, graduates and employers. The final draft was developed through an iterative process of expert review and refinement. The resultant learning outcomes were then further improved using a web based Delphi survey. The use of web based Delphi as a consensus tool has been promoted as an effective and efficient research tool for HRD and adult education research (Colton & Hatcher, 2004). A 4-point scale was used to rate 115 learning outcomes / competences. The results suggest that the mean was used as a measure of level of agreement which as discussed earlier was not advisable. There was no indication what method was used to measure level of consensus. Following quantitative and qualitative analysis, the draft was validated by an expert panel of the European Commission and accepted and approved by the Directorate of Education of the European Commission.

Eckler et al. (2016) in developing a competence profile for Austrian physiotherapists for year 2020 reviewed several documents (EU directives/European Network of Physiotherapy in Higher Education/ENPHE, European Skills, Competences, Qualifications and Occupations/ESCO, diverse documents of European institutes of higher education) to ensure the development of the profession within a national and European context. A competence profile was developed through a circular process with feedback and reflection loops. The resultant competence profile included the following key roles: Expert in Physiotherapy, Communicator, Collaborator, Manager, Health Care Promoter, Innovator and Professional. The researchers were all members of educational institutions and other stakeholders such as policy makers and employers were not involved. The report does not mention what quantities were used to measure levels of agreement and consensus. A similar study by Sjögren et al. (2016) used four different data sets include survey questionnaires, physiotherapists' group interviews, Delphi expert rounds and systematic literature review of core competencies to map physiotherapists' competences in Finland. The conference abstract seems to point out that participants were mainly physiotherapists and once again no information on measures of agreement and consensus were available. Both physiotherapists' projects failed to include other major stake holders.

Cumyn and Harris (2012) in validating the content of a curriculum for obstetric medicine first used SMEs to develop an initial blue-print from previous literature and other curricula without adopting a multi-stakeholder approach. Then the resultant inventory of learning outcomes was sent to a number of physicians who provided feedback on the items of the inventory. Respondents were asked to indicate for each item, whether it should be included, modified, or deleted. They were also asked to provide justifications for modifying or deleting content. 80% was pre-determined as the cut-off for consensus for items which would be definitely included in the Delphi survey. Finally, they were invited to indicate additional content they thought should be included. The results from this analysis led to the creation of a Delphi survey to obtain consensus on the more important or controversial changes that could be made in the curriculum blueprint. The mean, mode, median, and standard deviation were computed for each item on a 5-point Likert scale. A maximum of two rounds of Delphi was also fixed ahead of time in order to avoid discouraging participants from engaging in a lengthy process or to avoid having participants reach an artificial consensus in an effort to just get the job done.

Tse et al., (2006) used a social action research framework to develop a validated Competence-Based Curriculum for health professions students based on focus groups and surveys. Action research is a collaborative approach to resolve specific problems through participatory procedures. A limited multi-stakeholder approach was adopted by recruiting parents, employers and educators through flyers or by word of mouth instead of purposive sampling. This type of recruitment adopted in the study could somehow limit the level of expertise provided as the participants may not be experts in the field. Respondents representing both rural and urban areas throughout the research locale were solicited. Each focus group consisted of only one type of stakeholder and was composed of 3 to 10 participants. Following this the themes originating from the analysis of the focus groups were used to structure the inventory which was distributed amongst parents, educators (faculty) and employers (service providers and administrators) for feedback. A 5-point Likert scale was used to rate an inventory of 16 competence statements. The mean was used as a measure of level of agreement which as discussed earlier was not advisable and standard deviation as a measure of consensus.

Midlov et al., (2015) used a modified Delphi technique amongst a group of physicians to identify the core competences in basic and clinical pharmacology that a newly qualified physician requires. The first round was qualitative whereby experts were asked to express an opinion on the matter at hand. The results were then used to develop a questionnaire containing 95 competence statements that was returned to experts for rating. An analysis of the competence statements however indicate that the majority were either skill statements (starting with the phrase – *is able to*) or knowledge statements (starting with the verb – *understand*). In this study, the number of rounds (2) and level of consensus (75%) were defined *a priori*. In addition, the authors did not provide any data on the panel members' teaching experience and only included physicians with interest in clinical pharmacology. Therefore, the participants may have only accepted those competences which are strictly required for clinical pharmacology and not other specialities of medicine. The selection of the expert group is of importance in order to ensure that core competences really reflect what is expected from the professionals of tomorrow and what knowledge and skills are expected.

A well planned collaborative study was that by Wallengren (2011) where she also used a 3-round modified Delphi technique to identify a list of core competences for primary care of allergy patients. In the first round, she recruited specialists (lecturers in national training programmes) to identify gaps in the practice. The second and third round was however returned to general practitioners and nurses who were best positioned to assess the reality for allergy patients. The Delphi questionnaire comprised of 80 items and in the second round these were rated using a 4-point Likert scale. The mean was again used to measure level of agreement and statements that scored 3.25 or higher were included in the third round of the study. The use of the mean is debateable in such cases when distributions are rarely Gaussian. In the final round, the items were rated using a dichotomous scale (agree / disagree) and level of consensus was set a priori at 75%. The final list included 18 knowledge statements and 28 skill statements grouped under three topics: diagnostics, therapeutics and communication.

2.10 Conclusion

This chapter has discussed key definitions, meanings and debates within the literature on curriculum development in general and competence profiles and learning outcomes and their development in particular. The concept of competence within the EQF is explored in relation to learning outcomes with the ambiguity and contradictions surrounding this term being acknowledged. The research in learning outcomes seems to focus more on assessment rather than learning outcome development per se which is often ignored. Research studies on the development of biomedical physics learning outcomes for radiographers specifically for MRI are almost non-existent. The literature is consistent in stating that multistakeholder collaboration including representatives from the Ministry of Health, the Ministry of Education, public and private training institutions, and health professional organizations is a must in order to produce inventories of learning outcomes for competent health workforces that support the evolving healthcare needs of their communities.

The following chapters will now address each research objective in turn.

Chapter 3: Objective 1 - to develop and validate a 2020 vision of the MRI service portfolio for Malta.

3.1 Introduction

This chapter reports on how the researcher sought to forecast the 2020 future MRI services on the basis of the first dimension of the curriculum development framework as suggested by Lee et al (2013) and Huyghe et al (2013) i.e., the need for an involvement of all stakeholders. It looks at which MRI services are expected to be delivered by the year 2020 and therefore inform what competences and associated physics knowledge and skills would be needed by MR radiographers. The results were published in the journal Radiography as: Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020. Radiography, 21(1), 21-27 (Castillo et al., 2015b).

3.2 Background

Underpinning the focus of this study is a situation most radiographer managers will recognise: that high quality CPD courses are becoming increasingly expensive and time off for radiographers is becoming progressively limited owing to high workloads. It is thus important that CPD time is optimized by ensuring that content reflects more closely the specific learning needs of the particular group of radiographers for whom it is designed and the particular healthcare needs of the local population (Castillo & Caruana, 2013). In such circumstances, CPD content should be aligned to the forecasted future development of the local service portfolio the radiographers would be expected to deliver. When such a service portfolio has not been sufficiently developed locally it is important that the CPD planner carries out an own forecasting exercise to assess what the service would likely look like on the target date when the proposed service portfolio and associated CPD curriculum should be fully operational (in this case 2020).

Initial literature review and correspondence with international colleagues indicated that the way services are developed varies widely. One approach involves the development of country-wide guidelines set up by groups of experts. Unfortunately, such guidelines often take too long to be formulated and disseminated and often require extensive modification when applied to local contexts. Hence there is more need for decision making at the local level (World Health Organization, 2006; Markwell S., 2009; Tomlinson et al., 2013). In the case of smaller institutions, decision making may be based on individual physician subjective preference or be vendor driven. This may not always support closely the healthcare needs of patients (Wennberg & Gittelsohn, 1973; Wennberg, 2002; Stagnitti et al., 2005). The issue of the forecasting of service portfolios represents a formidable challenge to departmental managers, however, it also offers opportunities for research. Through this objective, the researcher presents one possible way forward that avoids the pitfalls of the two aforementioned approaches. This objective therefore targets the question: what MRI services will be required by year 2020 for the local Maltese clinical scenario? The answer to this question will inform the development of the competence profile of MR radiographers and hence the physics learning outcomes inventory.

The researcher utilized a methodology based on a multi-stakeholder Delphi group. Radiologists, radiography managers, medical physicists, policy makers, patient advocates and imaging equipment company personnel were first consulted via individual interviews. Interviewees were asked on their professional background and their role in MRI. Secondly, they were questioned on their views concerning the current service catalogue to enquire which current services should be retained. They were then questioned on which services lie in the pipeline, thus finding out what would actually be needed locally by the year 2020. They were also asked about their opinion on current MRI education to referrers and non-physicians in order to determine what level of knowledge would be required to ensure that requests are justified, on research in order to determine whether they would consider collaborating in research studies with the medical imaging department, and on changes in referral patterns to determine the likelihood of requesting for MRI services by general practitioners and other healthcare professionals. Finally, the services to be retired were discussed together with likely developments in service delivery arrangements and work practices. All these factors which involve social, historical, political, economic, professional and educational forces, have a direct influence on the contents of the service portfolio and also the development of learning outcomes (Lee et al., 2013).

The results of the interviews were used to develop an initial version of the service portfolio.

The final service portfolio was then developed and validated by the same group of experts using an online Delphi process.

3.3 Purpose

In this objective, the researcher sought to develop and validate a 2020 vision of the MRI service portfolio for Malta using a multi-stakeholder approach. This would indicate the present and future competences required of MR radiographers to deliver the present and envisaged future service provision and hence the necessary biomedical imaging physics knowledge and skills. Figure 3.1 depicts the service portfolio model that guided the study and is a simplified version of that proposed by Brailsford and Vissers (2011). It includes present service catalogue (here meaning the range of services that are available or ready for deployment), the service pipeline (here meaning proposed services or services in development) and retired services (here meaning services to be removed or already removed from the catalogue).

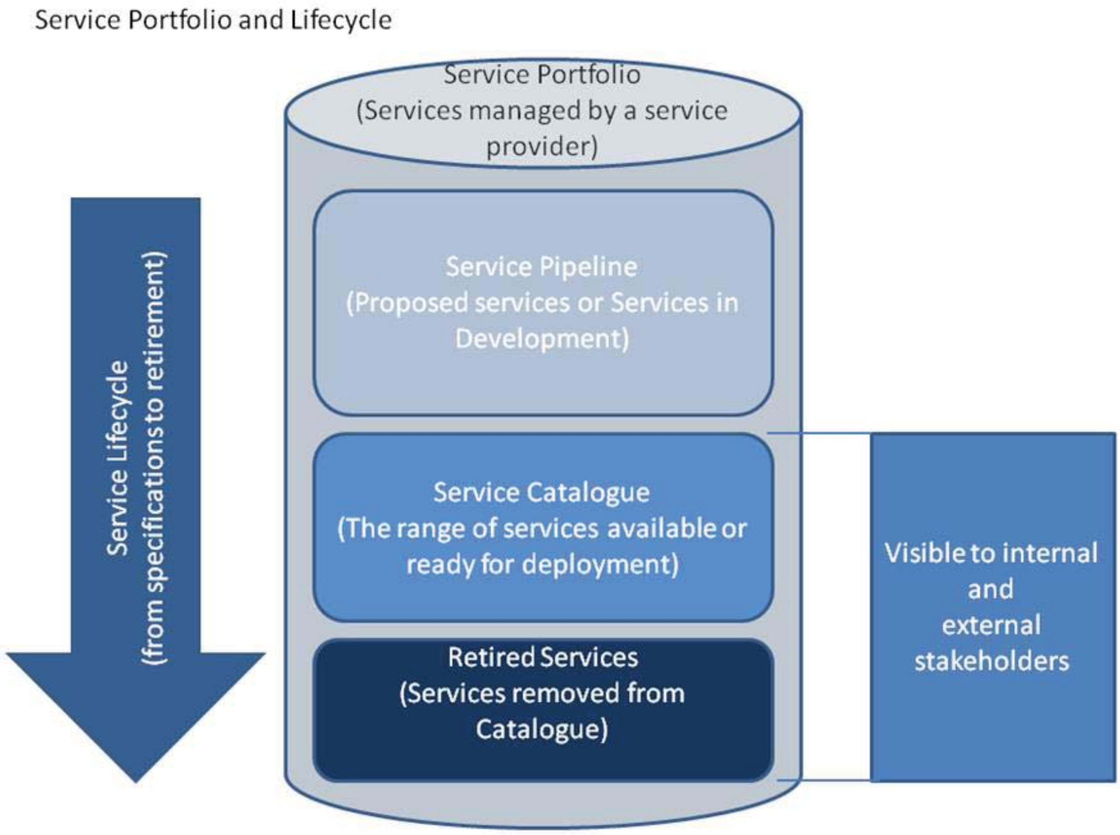


Figure 3.1 – Service Portfolio and Service Lifecycle

3.4 Methodology

Various techniques for the delineation of the service portfolio were considered. A survey of the literature revealed that research based on multi-stakeholder collaboration processes and using consensus techniques such as the Delphi, nominal group or focus group techniques are ideal (Jones & Hunter, 1995; Kitzinger, 1995; Hutchings et al., 2006). Three important practical issues were taken into consideration before deciding on the most appropriate technique to use: the technique needed to involve as many of the MRI stakeholders as possible, it needed to ensure that all participants could voice their opinions freely, and finally if possible be efficient in terms of time. The research technique chosen for this objective was the Delphi technique not only because it satisfies the aforementioned requirements but as it is also very suitable when idea generation and exploration, forecasting and expert judgment are indispensable (Linstone et al., 1975; Okoli & Pawlowski, 2004; Franklin & Hart, 2007). A focus group or a nominal group technique could also have been employed in collecting the data. However, considering the diversity of the stakeholders within the group and their busy schedule the researcher chose to collect the opinions of the panel using a Delphi technique. This technique is more suitable because it ensures the independence of the participants and allows them to change their opinion based on feedback from previous rounds. Dominance of the strongest and most eloquent speakers is also prevented while valuing the informed views of the less gifted speakers (Hasson et al., 2000; Keeney et al., 2006; Keeney et al., 2011). The Delphi like any other research instrument also suffers from limitations (Hasson et al., 2000). A Delphi technique may be time consuming and participants may therefore lose interest in the topic if consensus is not reached fast enough. With this in mind, the researcher planned the Delphi process to start off with initial individual face to face interviews carried out at the convenience of the various participants in order to develop an initial version of the service portfolio, and then use a web based questionnaire for final validation where again the participants would answer at their convenience.

The recruitment of a suitable panel of SMEs is fundamental to the success of the Delphi approach, as it relies on consensus having been reached by authentic experts in the field. Hasson et al (2000) in an article on Delphi guidelines cite definitions of an expert as an informed individual, a specialist in the field, or someone who has knowledge about a specific subject.

Within this context the researcher sought to gather opinions from a purposive sample of key stakeholder experts (n = 17) coming from healthcare policy, general radiology, imaging unit management, orthopaedics, neurology, medical physics, MRI industry and patient advocates that are involved in or would have an impact on local MRI development or as in the case of vendors have access to insider information on new technology impacting the service pipeline. Gillham (2005) refers to this approach as the 'elite interview' approach and involves talking to people who are most knowledgeable about the research area and/or who would have major impact on its development.

The rationale for including each type of expert is given in Table 3.2. The experts were chosen on the following criteria:

1. Are acknowledged local experts in the field.
2. Are in a position to influence the development of local MRI services.

The first round of the Delphi was carried out through individual semi-structured interviews to provide maximum space for idea generation and elaboration. In order to ensure content validity of the interview tool, the latter was structured to follow directly the structure of the service portfolio model shown above and was divided into 4 sections. Section 1 focused on the interviewee's role in MRI and his / her potential impact on the present and future MRI service portfolio; section 2 focused on the present service catalogue; section 3 was dedicated to services in the pipeline; in section 4 participants were asked for their opinion regarding which of the services presently on offer may be side-lined by 2020. The tool was further validated by the ABoE. The tool was piloted with three experienced foreign MR stakeholders (including radiographers) to assess the clarity of the questions. The tool can be seen in Appendix B.

A letter of invitation was emailed to each participant providing them with an information sheet explaining the purpose of the study and a consent form. The participants were also provided with the interview questions in advance so that they might reflect on the issues prior to the interviews. All interviews were carried out at a place chosen by the participant. At the start of the interview the purpose of the research was explained and an assurance of confidentiality was given. All participants were asked for permission to record the interview. In all cases permission was granted. The interview then commenced and was recorded on audio tape. The questions were paced and sequenced to lead the conversation towards the key questions of the study (Berg, 2004). Interviews generally lasted approximately 1.5 hours.

The subsequent qualitative analytical process used was based on Braun and Clarke's (2006) six phase framework and is summarised in Table 3.1.

Phase	Description
1 Familiarizing with the data	The data were transcribed verbatim. At this stage, the researcher familiarised with the data gathered from the semi-structured interviews by reading the transcripts, the interview notes, and listening to the tapes several times. Here the researcher immersed himself in the overall discourse of the participants and slowly becoming aware of recurrent themes and ideas.
2 Generating initial codes	Immediately after transcribing all transcripts, each transcript was transformed into a concept map using CMAPTOOLS (Institute for Human and Machine Cognition) (see an example in Figure 3.2) to identify interesting codes from the entire data set.
3 Searching for themes	By this stage, the researcher finished the preliminary coding of the 11 concept maps and ending up with a substantial number of codes. Using NVIVO10 (QSR International, 2013) these codes were entered as nodes and were systematically applied to all the transcripts lifting the data from its original textual context (transcripts) while highlighting and making comparisons, both within and between transcripts.
4 Reviewing themes	This was the process during which the evolving thematic framework consisting of nodes was indexed to transcripts as shown in Figure 3.3. Gradually, emerging ideas derived from the data were reconstructed into themes when organisational patterns became apparent. These themes were again checked in relation to the coded extracts and the entire text verifying whether each code was a true representation of participants' discourses. The themes were also checked and compared to the original concept map.
5 Defining and naming	Clear definitions and names for each theme were in this case confirmed. The references were collapsed and guided the

themes	development of statements for the service portfolio.
6 Producing the report	A scholarly report of the analysis was produced.

Table 3.1 – Braun and Clarke's six phase framework as modified for this study

Concept maps were created for each interviewee using CMAPTOOLS (Institute for Human and Machine Cognition), and subsequently analysed for levels of hierarchy, interconnections and repeated concepts to identify emerging themes and elaborate on existing ones and had already been used successfully by the author of the thesis in a previous publication (Novak & Cañas, 2008a; Castillo & Caruana, 2013). An example of a concept map generated during the project can be found in Figure 3.2.

Concept maps have been used as a strategy to deal with the methodological challenges of qualitative research (Novak & Cañas, 2008b). A concept map can be used to frame a research project, reduce qualitative data, analyse themes, establish interconnections in a study, and present findings (Daley, 2004). ''A concept map is a schematic device for representing a set of concept meanings embedded in a framework of propositions'' ((Novak & Gowin, 1984), p15). Concept maps are created with the broader, more inclusive concepts at the top of the hierarchy, connecting through linking words with other concepts that can be subsumed. Concept maps are an important strategy in qualitative inquiry because they help the researcher focus on meaning. The maps allow the researcher to see participants' meaning as well as the connections that participants discuss across concepts. Additionally, the maps support researchers in their attempts to make sure that qualitative data are embedded in a particular context.

Concept maps also can be used as a strategy to search out and analyse themes in qualitative research (Burgess-Allen & Owen-Smith, 2010). To identify these overarching themes, the researcher has to identify inter-connections between concepts. If the researcher is searching for specific interconnections, a concept map can be created from the transcripts to demonstrate these connections. For example, in one study on how professionals learn, the researcher was looking for the connections participants made between what they learned in formal continuing education programs and their professional practice (Daley, 2001). Concept maps can also be used to help create a category or coding scheme in qualitative research. After the maps are created from each interview, the researcher can go through them looking for levels of hierarchy, interconnections, and repeated concepts. These items then may indicate emerging themes (Daley, 2004). The major disadvantage of using concept maps in qualitative work seems to be their complexity. The maps can be difficult to read for participants unfamiliar with the format, and the linkages may be harder to see as the maps get more and more complex. Additionally, the complexity at times makes it difficult for the reader to determine which concepts are of critical importance and which are of secondary importance. Concept maps in this study were used to reduce the qualitative data so as to facilitate the process of understanding key ideas.

For the second round of the Delphi, a web based second-round questionnaire was developed based on the themes generated in the first-round interviews. It is shown in

Appendix C. The second round of the Delphi study was conceived as a consensus seeking round in which participants were asked to register their level of agreement with a list of close-ended statements generated from the first round data. The list of statements is shown in Table 3.3. The following Likert scale was used: 1= completely disagree; 2 = generally disagree; 3 = slightly disagree 4 = slightly agree; 5 = generally agree; 6 = completely agree. No neutral (‘neither agree nor disagree’) point was used as suggested by Beaudin (1999) but each participant was given the option to comment on each statement. In order to ensure content validity of the Delphi tool, the latter was based directly on the model of the service portfolio of Figure 3.1 and on the themes identified in the interviews. The tool was further validated by the ABoE. The tool was piloted by three foreign stakeholders (including MR Radiographers with Master’s degree and experience in MRI management) to ensure the adequacy of the information sheet, the clarity of instructions, items included, adequacy of response options and time taken for completion. The study was pseudo-anonymous in the sense that although the respondents were known to the researcher, they were kept anonymous to each other. Ethical approval was granted by the research ethics committee of the University of Malta (proposal no 124/2012 and 084/2013).

Figure 3.2 - Concept map from radiographer manager

3.5 Results

The response rate in the first round was 65% (n=11). Non-respondents in the first round were re-invited to participate in the second round. The response rate in the second round increased to 88% (n = 15). The composition of the expert panel for the second round is shown in Table 3.2. Since the non-respondents in the first round did not have additional comments when probed it was considered that the second-round questionnaire included all views to their satisfaction.

Participant	Current Position	Rationale for inclusion as Expert Stakeholder
1	Orthopaedic Surgeon	Orthopaedic department is one of the main referrers for MRI
2.	Neurosurgeon	Neurosurgery department is one of the main referrers for MRI
3	Director of Company importing Medical Imaging Equipment.	A potential provider of new MRI technology
4	Manager, Medical Physics Services	Medical Physicists are one of the professions involved in MRI
5	Neurologist	Neurology department is one of the main referrers for MRI
6	Patient advocate	Qualified nurses directly involved with the care of patients in an orthopaedic/surgical/neurology ward
7	Radiologist	Consultant Radiologists are one of the professions involved in MRI reporting on Neurology/ Orthopaedic cases
8	Manager, Physiotherapy Services	Physiotherapists use MR Images to plan treatment of patients.
9	Director of a Private Hospital with major imaging facilities	Represents the private MR imaging sector.
10	Manager, Radiography Services	Radiographers are one of the professions involved in MRI.
11	Policy maker	Policy makers are involved in decisions during the setup of new services and outsourcing.
12	Director of a company importing Medical Imaging Equipment	A potential provider of new MRI technology
13	Patient advocate	Qualified nurses directly involved with the care of patients in an orthopaedic/surgical/neurology ward

14	Director of a company importing Medical Imaging Equipment	A potential provider of new MRI technology
15	Director of a company importing Medical Imaging Equipment	A potential provider of new MRI technology

Table 3.2 - List of participants and rational for selection. 1-11 took part in the first round (interviews)

The coding process as described for NVIVO10 (www.qsrinternational.com) was carried out immediately following the first-round interviews. The codes identified from the concept maps were used as nodes and each node was mapped to a source (interview) and indexed. Diagram 3.3 shows indexing using NVIVO. The bottom panel in this diagram is an example of transcript excerpts that were indexed under a node (later to become a theme). This resulted in 216 references which guided the development of the statements for the second-round questionnaire.

The final list of themes was:

- Staff and public education
- research
- current procedures
- technical expertise
- future services and technology
- legislation, quality and safety considerations
- accessibility to patients and non-medical referrers

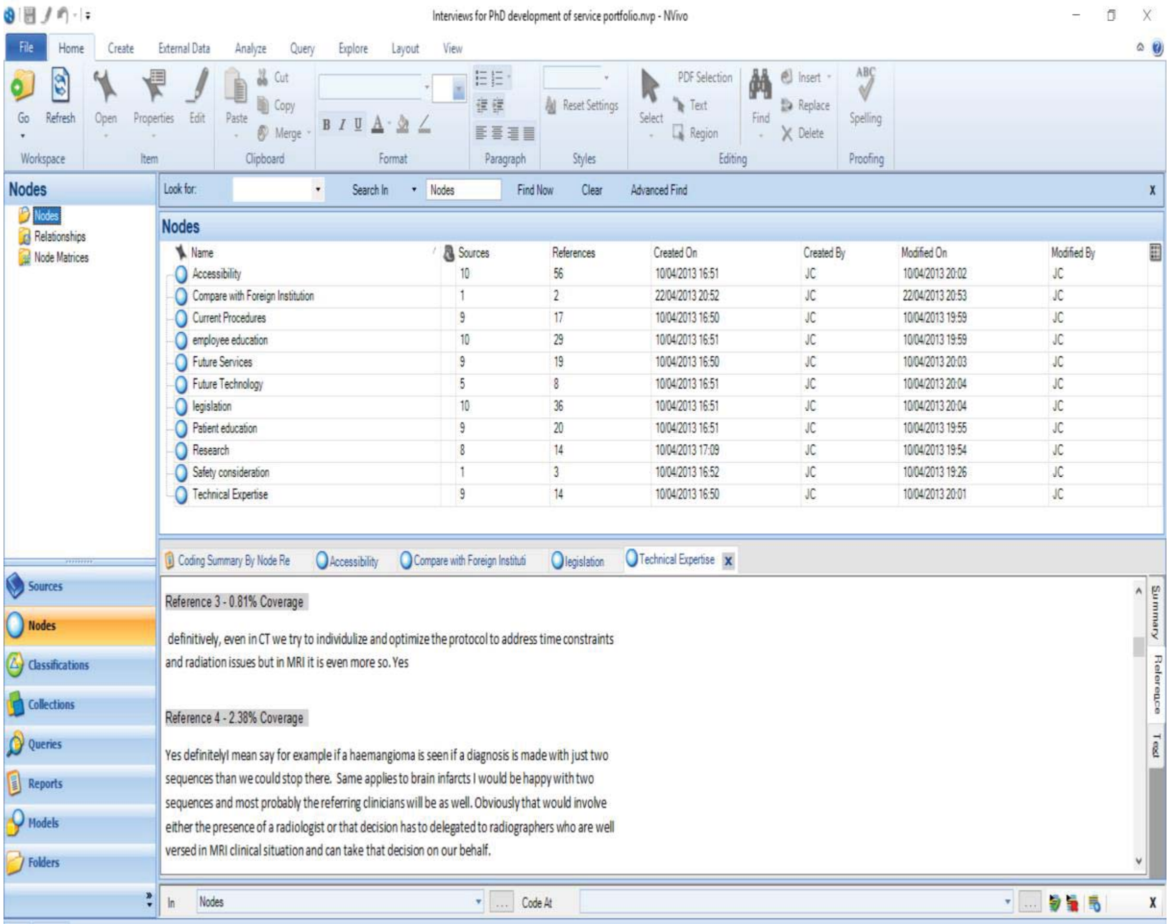


Figure 3.3 – Indexing using NVIVO10

The measures of level of agreement and level of consensus used in the second round validation Delphi were the median and inter-quartile range (IQR) respectively (Crisp et al., 1997; Rayens & Hahn, 2000; Hsu & Sandford, 2007; von der Gracht, 2012). Delphi studies are often stopped when an IQR of 1.0 or less is attained on the greater majority of the probed statements (von der Gracht, 2012; Shaikh, 2013). The criterion for consensus as IQR less or equal to 1 was considered a stringent criterion. In this study 90% of the statements achieved an IQR of 1.0 or less following the second round of the Delphi and the Delphi was therefore stopped at this stage. The results of the second round are also given in the Table 3.3. All statements achieved a median equal to or higher than 5 indicating a high level of agreement with the statements; 26 statements achieved a median of 6 ('completely agree with the statement'), and 15 statements a median of 5 ('generally agree with the statement'). In terms of level of consensus out of 41 statements, 3 achieved an IQR of 0 (total consensus), 33 statements resulted in an IQR of between 0.1 and 1.0 (moderate to high consensus) and 5 statements received an IQR of 1.5 and more (low consensus). The latter are shown in red in the table 3.3. All statement distributions were checked visually to be unimodal before calculation to exclude bimodality (Rayens & Hahn, 2000).

Statement No	Statement	Median	IQR
MRI Present Service Catalogue			
1	Demographic Information	-	-
2	Neurology MRI including Diffusion weighted imaging should continue to form part of the service catalogue.	6.0	1.0
3	Body MRI should continue to form part of the service catalogue.	6.0	1.0
4	Musculoskeletal MRI should continue to form part of the service catalogue	6.0	0.0
5	Vascular MRI should continue to form part of the service catalogue	6.0	1.0
6	Breast MRI should continue to form part of the service catalogue	6.0	1.0
7	MR Cholangiopancreatography (MRCP) should continue to form part of the service catalogue.	6.0	1.0
8	MR Neurography (e.g Brachial plexus) should continue to form part of the service catalogue.	6.0	0.5
9	MRI prostate imaging should continue to form part of the service catalogue.	6.0	1.0
10	MRI female pelvis should continue to form part of the service catalogue.	6.0	1.0
11	Paediatric MRI should continue to form part of the service catalogue	6.0	1.0
12	MRI with general anaesthesia should continue to form part of the service catalogue	6.0	0.5
13	MR arthrography should continue to form part of the service catalogue.	6.0	1.0
14	MRI planning for Deep Brain Stimulation should continue to form part of the service catalogue.	6.0	0.5
15	On call services should continue to be provided on a 24 / 7 basis.	6.0	1.0

16	**Outsourcing should only be considered after all other options in reducing the waiting time have failed.**	**5.0**	**2.0**
MRI Service Pipeline by 2020			
17	Information on the diagnostic utility of different pulse sequences in the various areas of healthcare should be provided to healthcare professionals.	5.0	1.0
18	Information on MRI legislation should be provided to all healthcare professionals.	6.0	1.0
19	Evidence based referral guidelines should be made available to all MRI stakeholders.	6.0	0.5
20	Information about the strengths, limitations and safety of MRI should be made available to the general public.	6.0	1.0
21	MRI courses should be developed for MD and non-MD referrers.	5.0	1.0
22	**All referrers should be certified in MRI referral before being granted MRI referring privileges.**	**6.0**	**1.5**
23	MRI education to all professions involved in MRI should be quality assured.	6.0	1.0
24	**All professions involved with MRI should participate in research**	**5.0**	**2.0**
25	Local MRI departmental regulations and procedures should be constantly updated to any EU legislation and documentation.	6.0	0.5
26	Referral guidelines would be used to prioritize accessibility to services.	6.0	0.0
27	Standard operating procedures regulating non-MD referrals would be needed as non-MD referrals will become more common.	6.0	1.0
28	MR tractography (MRI of neural tracts of the brain) should form part of the MRI Service catalogue	5.0	1.0
29	**3T Imaging should form part of the MRI Service catalogue.**	**5.0**	**2.0**
30	MRI guided biopsy of the breast should form part of the MRI service catalogue.	6.0	1.0
31	Diffusion weighted imaging for non cerebral work should form part of the MRI service catalogue.	5.0	1.0
32	Cardiac MRI should form part of the MRI service	6.0	1.0

	catalogue.		
33	Breast MRI as a screening tool for family screening should form part of the MRI service catalogue.	5.0	1.0
34	Oncology planning with MRI fusion imaging should form part of the MRI service catalogue.	5.0	1.0
35	MRI-PET should form part of the MRI service portfolio.	5.0	1.0
36	Elastography imaging which is used for evaluating liver cirrhosis should form part of the MRI service catalogue	5.0	1.0
37	Dynamic MRI for patellar tracking should form part of the MRI service catalogue.	5.0	1.0
38	MRI enterography (small intestine imaging) should form part of the MRI service catalogue.	5.0	1.0
39	**Prostate MRI as a screening tool should form part of the MRI service catalogue.**	**5.0**	**1.5**
40	Assessment of change in tumour burden as a measure of treatment response or tumour progression should form part of the MRI service portfolio.	5.0	0.5
41	The quality and safety of the MRI service should be ISO assured.	6.0	0.0
MRI Services to be side-lined			
42	Given the present level provision of MRI services none of the present services should be side-lined.	6.0	1.0

Table 3.3 - Statements for the second round of the Delphi with corresponding median and IQR values

3.6 Discussion

The results of the Delphi are discussed individually below theme by theme.

Staff and public education

At present MRI education and training for healthcare professionals in Malta includes an MSc Radiography (MRI) of the University of Malta and a MSc Medical Physics which includes an MRI component for Medical Physicists majoring in Diagnostic and Interventional Radiology. Radiologists also follow a similar programme and sit for the examinations of the Royal College of Radiology (UK). The experts in this study strongly agree that the present MRI educational provision to all professions involved in MRI should be quality assured (statement 23: median=6.0 IQR =1.0) and that the educational provision should be widened to include MD and non-MD referrers (statement 21: median=5.0 IQR=1.0), Education on MRI legislation should also be made available to all healthcare professionals (statement 25: median=6.0 IQR=0.5). The latter is crucial because on 26th June 2013 the EU adopted Council Directive 2013/35/EU on minimum and health and safety requirements during work carried out in electromagnetic fields. This Directive is intended to address all known direct biophysical effects and indirect effects caused by electromagnetic fields, in order to not only ensure the health and safety of each worker on an individual basis but also require employers to ensure that risks arising from electromagnetic fields at work are eliminated or reduced to a minimum. In August 2013 the European Commission issued a call for tender to draw up a guide of good practice on MRI safety (European Society of Radiology, 2013). Compliance with safety regulations should not be difficult for the MRI community, which being part of a medical imaging department, is well aware of the need for protection from physical agents. Public education also received a high level of agreement and consensus (statement 20 median=6.0 IQR=1.0) with many of the participants suggesting ways how to achieve this objective.

'I think that if we use the same model as that used in the healthcare fair or a campaign it would reach many people for example when there is a campaign about sports injury for example MRI education should be part of it.' (participant 3)

Research

Experts confirmed that apart from a few Master's Degree projects by MRI radiographers there has been very little research activity being carried out. This was expected owing to the relatively recent introduction of locally based MRI education. Although experts were generally in favour of research activity, the level of consensus is low (statement 24: median=5.0 IQR=2.0). The high IQR resulted from the lower level of enthusiasm for research by the private sector. This was again expected as in the present circumstances research services do not lead to profit locally. However, all participants reiterated that they would support all requests from individuals or group of healthcare professionals to carry out research.

Current procedures

The results indicate that MRI is still considered as the gold standard for patients who require neurosurgical or orthopaedic operations as well as those who require neurological investigations (statement 2: median=6.0 IQR=1.0; statement 4: median=6.0 IQR=0.0; statement 8: median=6.0 IQR=0.5; statement 14: median=6.0 IQR=0.5). Clinicians expect that requests for MRI services are going to increase and become even more complex as indicated by participant 1 who stated:

'We are actually one unit of the hospital that needs the services of this MRI and I can imagine that our service is going to increase…'.

Technical Expertise

The group highlighted the importance of utilizing protocols that address specific clinical questions rather than a one protocol fits all approach (statement 17: median=5.0 IQR=1.0). This is particularly relevant in MRI where magnet time is expensive and additional sequences and unnecessarily long scanning times are undesirable (Saunders et al., 2007). Other experts in the panel reported an advisory role for radiographers and medical physicists in the setting up of quality assurance programmes mandated by EU legislation (statement 25: median=6.0 IQR=0.5) or in serving as a communicator between patient and the MRI unit or the referring consultant (statement 20: median=6.0 IQR=1.0). This advisory role can also assume an overall objective of developing safety policies and procedures to provide standard of protection of patients and staff in the MRI unit (Kanal et al., 2004; McRobbie, 2007).

'Yes definitely I mean say for example if a haemangioma is seen if a diagnosis is made with just two sequences then we could stop there. Same applies to brain. Obviously, that would involve either the presence of a radiologist or that decision has to be delegated to senior radiographers who are well versed in the MRI clinical situation and can take that decision on our behalf.' (Participant 7).

'If I need a specific sequence I would request it of course with discussion with radiologist, radiographers to build up the knowledge. This I have found to be extremely important over the years' (Participant 5).

Future services and technology

The level of agreement in terms of the median for the introduction of MR Tractography, Elastography, Dynamic MRI for patellar tracking, DWI for non-cerebral work, MRI enterography, oncology planning and MRI-PET was 5.0 and all with a high consensus level (IQR =1.0). Cardiac MRI achieved a higher level of agreement (statement 32 median 6.0 IQR=1.0)

'The first thing that comes to mind is cardiac MRI. It is a missing link in the department because we are going to have a 64 slice CT scanner, but not MRI cardiac.' (Participant 4).

There was less consensus on the introduction of 3T and prostate cancer screening (IQR=2.0, 1.5 respectively). This is quite surprising because prostate cancer detection and characterization has benefited from the introduction of 3T MRI scanners, improved diffusion-weighted sequences with fewer artifacts, better image-processing methods and MRI guided biopsy (Tanimoto et al., 2007; Choyke & Turkbey, 2013; Gupta et al., 2013; Kirkham et al., 2013; Li et al., 2013). In addition Ahmed et al (2009) reiterate that the use of MRI before biopsy can serve as a screening tool in men with raised serum prostate-specific antigen. This strategy could lower costs by avoiding biopsies.

Legislation, quality and safety considerations

Of interest, and this augurs well for the radiography and medical physics staff is that ISO accreditation, safety, referral guidelines and adherence to EU legislation had a high level of agreement (statements 19, 25, 26,41 median=6.0) and the highest level of consensus (IQR=0.5, 0.5, 0.0 and 0.0 respectively). Radiographers and medical physicists should be qualified to understand and contribute to site planning, specification and procurement of MRI devices, pre-imaging screening of patients, and addressing safety in paediatrics, pregnancy, and devices (Shellock & Spinazzi, 2008a, 2008b). Referral guidelines on making the best use of an MRI Department should be available and if used appropriately would reduce waiting times. Picano (2004) notes that a third of radiological investigations are totally or partially inappropriate and suggests that referrers should be required to have a radiological driving licence.

'I think in the right context there is an important role for non-MD referrals typically what comes to mind is referrals by physiotherapists and general practitioners however I say this with a degree of apprehensiveness' (participant 7).

Accessibility to patients and non-medical referrers

When asked if they envisaged any changes in referral patterns, the participants reported that if the education of non-MD professionals becomes broader and more in depth then there is the possibility that certain routine examinations such as lumbar MRI could be requested by non-MD.

'Secondly…. We are working on these extended skills - nurses would have the opportunity to request MRIs …' (Participant 1).

'*for example,…. specialized nurses could request MRI spine. No objection to that. … if you have someone who spends two years in this field he/she will eventually learn who requires an MRI and who doesn't…'* (Participant 2)

However, since referral patterns are traditionally based on physician advice these changes are unlikely to happen any time soon. Experts hope that this change is done gradually, be evidence based and supported by education.

'Every referral needs to be vetted by a person who knows the true value of the exams requested and who can advise whether MRI is really the best option…. referral patterns will probably remain the same as patients normally prefer a Doctors' advice.' (Participant 9)

MRI referral by non-physician such as extended scope physiotherapists is now becoming more common (Inman et al., 2009; Newsome et al., 2012) and recent studies have shown that with higher education non-MD practitioners can be cost effective whilst making the best use of MRI scanners (Inman et al., 2009; Shannak et al., 2010; Locke, 2011). Within this context referrers must be educated in MRI and a standard operating procedure must be established ensuring that every request be vetted by an expert in MRI and who can advise whether MRI is the best option. There was low consensus amongst experts on whether all referrers must be certified in MRI education before being granted referral privileges (statement 22: median=6.0 IQR=1.5). The non-MD experts in the panel reiterated that although health care practice in Malta is moving in this direction more education is required and the establishment of evidence based referral criteria is a must (statement 27: median=6.0 IQR=1.0).

In response to the question of requests by non-medical healthcare professionals for MRI procedures and self referrals by patients, the experts in the panel were of the impression that although at the local general hospital only consultant clinicians are permitted to request MRIs, in reality the requesting privileges were often delegated to junior doctors.

'Well I am under the impression it should be the consultant clinicians both from any speciality and resident speciality, but I am also aware that this privilege is often delegated

to junior doctors. I am not sure whether this is good practice but I am told that it is allowed in our institution and basically this does give rise to some confusion.' (Participant 7)

In the private setting the mix of referrers is dictated by private insurance schemes. By default, insurance policy dictates that MRI scans must always be referred by a consultant and as a result 70% of the requests in the private setting originate from consultants. On the other hand, in the case of self-funded patients 15% are referred by the local general practitioner, 10% by non-MD and 5% are self-referred. As regards the latter, these patients are still required to be seen by a consultant radiologist attending at a private clinic. Self-referrals are not accepted at the local general hospital even though experts within the panel commented that they do meet patients who demand to have an MRI scan as indicated by participant 5:

'Some people do turn up to request MRI. Here the consultant will discuss the justification for MRI with the patient. Some people understand others don't and will seek other clinicians.'

Although MRI accessibility has improved there seems to be differences in referral policies between states. An Italian study suggests that MRI can be requested by General Practitioners and may have increased the number of inappropriate requests (Prota et al., 2012). In Australia, accessibility has been made available to GPs and although the report indicates that savings were observed in terms of fewer CT scans and fewer specialist referrals and consultations, GPs should have adequate training (Chawda et al., 1997; Bradfield, 2009). Perhaps widening further the accessibility to MRI at the local general hospital as well as in the private setting to general practitioners, may alleviate the waiting time if referral guidelines are implemented and quality education to GPs implemented (Bradfield, 2009; Simpson et al., 2010).

The majority of experts were aware of two outsourcing schemes and the majority of experts working at the local public hospital agreed that outsourcing should only be considered after all available options have been exhausted. Experts reported that from experience outsourcing does not allow control over costs, customer satisfaction, and assurance of quality and standards of care. Outsourcing routine cases only, was also considered as verging on unethical because complex cases would be processed too slowly. It was also mentioned that outsourcing should only be considered if the financial implications are advantageous with respect to buying a further magnet at the public hospital. Experts from the private sector have reported that their institutions are well placed to address the increasing requests through private-public partnership. This difference between experts working in the public hospital and those coming from the private sector was manifested in a low level of consensus (statement 16: median=5.0 IQR=2.0).

3.7 Conclusion

This objective has proposed a research based methodology for forecasting the development of the MRI service portfolio for Malta. The results highlight important current issues related to ISO certification of MRI quality and safety; the development of MRI referral guidelines and the updating of local MRI policies and procedures to EU legislation. The experts also identified new services that should be considered a priority. Outsourcing was not seen as a viable option to address waiting lists with the majority of experts from the public hospital preferring to procure additional MRI scanners. The multi-stakeholder approach has provided valuable insight into the local MRI scenario especially the flexible referral system in the private sector and insurance policies. The multi-stakeholder approach has also provided novel insight in particular to the fact that MRI education should be quality assured and if it is provided to non-MD that there is a possibility that non-physicians could be in a position to request MRI procedures even if at first this would be limited in scope. Overall, the experts are of the opinion that the use of MRI is expected to continue to increase across all specialities. This will result in a significant impact on practice, skill-mix requirements and management policies for the foreseeable future. These factors will also impact the radiographer's responsibilities throughout the MRI clinical pathway and will be reported in the next chapter.

Chapter 4: Objective 2 - to optimize the care pathway for MRI services in Malta

4.1 Introduction

This chapter reports on how the researcher sought to optimize an MRI care pathway and identify the quality criteria for each step of the pathway. The results would inform which competences would be needed by radiographers in order to understand and be able to deliver the MRI care pathway in an effective, safe and efficient manner. The results of the study were accepted for publication in September 2014 as: Optimizing a magnetic resonance care pathway: A strategy for radiography managers. Radiography, 21(1), e29-e33 (Castillo et al., 2015a).

4.2 Background

At the MRI unit level, service quality is contingent on the design of the care pathway through which the MRI service is delivered and experienced by patients(Johnston & Clark, 2005; Yazdanparast et al., 2010). Hence, an optimised care pathway design is crucial for the attainment of an effective, safe and efficient service (Cheah, 2000). This objective targets the optimization of such a local care pathway as initially perceived and developed by the researcher based on personal experience, direct observation and input from local colleagues. A search of the literature did not result in any studies regarding the optimization of MRI care pathways through a formal research process. Discussions with international MR radiographers indicated that such development is often carried out using informal methods that are highly dependent on local conditions, that are rarely reported in the public domain and the validities of which are therefore not open to scrutiny. Care pathways need to be specific to local healthcare needs and culture. The optimized pathway will examine the journey from when the referrer considers submitting a request for MRI to the medical imaging department all the way till the patient is referred back. The underlying principle for this objective is that rather than looking at practice as being solely the application of knowledge and skills gained during traditional modes of study, it is important to consider the clinical environment as the locus where complex professional competence is enacted and developed (Cetina et al., 2005; Green & Green, 2009). Since becoming and being a health professional is substantially learned on the job through practice and systematic critical reflection, the specific steps along the clinical pathway should be considered as an opportunity to provide input to curriculum development.

The European Pathway Association (http://www.e-p-a.org) defines a care pathway as: "A complex intervention for the mutual decision making and organization of predictable care for a well-defined group of patients during a well-defined period. Defining characteristics of pathways include: an explicit statement of the goals and key elements of care based on evidence, best practice and patient expectations; the facilitations of the communication and coordination of roles and sequencing the activities of the multidisciplinary care team, patients and their relatives; the documentation, monitoring, and evaluation of variances and outcomes; and finally the identification of relevant resources". This objective targeted "the facilitations of the communication and coordination of roles and sequencing the activities of the multidisciplinary care team" in order to identify the competences that would inform the development of the competence profile and hence learning outcomes.

The design of clinical care pathways combines a variety of methods from the quality improvement and operational research literature. Such literature indicates that a critical characteristic to consider with respect to the sequencing of activities of the multidisciplinary care team is the coordination model required. Vanhaecht et al (2010) describe three different coordination models: chain, hub and web models. Chain models are used for relatively highly predictable care processes with a high level of agreement between the team members. Hub models are used for less predictable processes; in this model, key persons will lead the organization of the care process. Web models are used for highly unpredictable, complex processes (Vanhaecht et al., 2010). Diagnostic radiology, as a whole would fit the hub model whilst the MRI care pathway sub-process fit a chain model with elements of flexibility as when practice involves a mix of routine and non-routine tasks, employees need to be able to take initiatives in response to incidental findings or to optimize processes beyond the confines of standard operating procedures (Ponsignon et al., 2011).

4.3 Purpose

The researcher sought to optimize the care pathway for MRI services in Malta using a multi-stakeholder approach based on the well-established nominal group technique (NGT). This would indicate the competences required for the delivery of an optimised patient care pathway and which would need to be included in the competence profile of the MR radiographer and which in turn would inform the physics learning outcomes inventory.

4.4 Methodology

Various consensus techniques for the optimization of the care pathway were considered. Four important practical issues were taken into consideration before deciding on the most appropriate technique to use: the approach needed to involve as many of the MRI stakeholders as possible, it needed to be based on a consensus building approach, to ensure that all participants could voice their opinions freely, and finally be efficient in terms of time as participants were busy professionals. These are the defining characteristics and strengths of the NGT technique. NGT methods gather a number of specifically invited experts, commonly 10–15, for a structured meeting on a specific subject (Fink et al., 1984). As a result, the resulting discussion would remain focused and easily controlled. The purpose of the NGT technique is to generate ideas, which are then discussed and ranked by the group (Delbecq et al., 1975). The group is highly controlled, with discussion occurring only in the later stages of the process. A facilitator guides and controls the meeting by collecting ideas from participants, as opposed to leading the discussion (Potter et al., 2004). The work of the facilitator is usually complemented by one or two other individuals acting as note-takers and co-ordinators of activities. The technique aims to avoid the known pitfalls of group interviews where some participants can be silent or feel intimidated in the presence of more articulate and dominant personalities. In NGT all members have an equal opportunity to contribute (Potter et al., 2004). The nominal group technique as described by Wainwright et al (2013) was adopted for this study. To kick-start the process an initial model of the MR care pathway for adults was developed by the researcher based on own experience, direct observation and validated by the ABoE as an appropriate initial model. The model was forwarded to the invited participants who were invited to give feedback regarding any modifications required. This ensured that the participants would focus more on the actual optimization of the pathway during the NGT process proper. The NGT method used in this study is summarised in Table 4.1. An NGT user guide (Appendix D) developed by the researcher and validated by the ABoE was used to ensure that no steps were left out that would jeopardize the NGT process. The final process in the actual study took approximately 2 hours and generated quantitative rankings of key optimization related issues.

Step	Comment
1. Introductory statement	The initial care pathway model was projected on a screen and participants requested to confirm or otherwise whether it was suitable to kickstart the process or whether a major modification was required. The initial care pathway was confirmed as suitable by all the participants. A set of guiding questions was also presented.
2. Initial generation of issues individually	For the next 20 minutes participants were asked to silently list issues on the paper provided.
3. Round-robin listing of ideas	The participants were asked to articulate briefly each issue until all issues were exhausted. Issues were recorded on a flip-chart.
4. Clarification of issues	The group was then asked to consider each item on the list to ensure common understanding. No items were omitted or merged so that all ideas were given their due importance (Steward, 2001)
5. Generation of individual top 10 lists	The participants were asked to individually select and prioritize the 10 issues that they felt were most important and record them on a worksheet.
6. Rating of issues according to relative importance	The worksheets were collected, and the issues and rankings noted.
7. Time out and icebreaker	The rankings for each individual issue were summed to give a total score.
8. Group discussion of most important issues	The top 15 issues were presented to the group for discussion with the facilitator only intervening to ensure focus. These were eventually condensed to 10 issues.
9. Final ranking of issues	Participants were asked to individually rank the 10 issues in order of importance. This time the participants assigned a weighting to each item, with the most important issue receiving a weighting of 100 and the least important a weighting of 1. The eight remaining issues were given a weighting between 1 and 100.
10. Conclusion	The final list of 10 ranked issues was presented for final discussion. Participants were thanked for their participation and subsequently informed of the findings.

Table 4.1: The NGT method used in the study.

The recruitment of knowledgeable participants is fundamental to the validity of the NGT approach. A purposive sample of expert health care practitioners was sought. 17 participants, representing radiologists, radiographers, management, medical physicists, policy makers, physiotherapists and nurses working in orthopaedics, neurosurgery and neurology were selected. The intention was to create a balanced representation of expertise from various sectors of professionals working in collaboration. Ideally the group of participants should also have included patient representatives. Unfortunately, patient associations are still very much in their infancy in Malta, hence senior nursing officers who have themselves been MRI patients or had close family members referred for MRI and are in communication with inpatients undergoing MRI were chosen to act as patient advocates. This had the added advantage that bias resulting from power inequalities between patients and healthcare professionals was avoided (Vaartio-Rajalin & Leino-Kilpi, 2011). Since conduction of the NGT session in a clinical setting may influence participant responses, the session was carried out at a leading hotel. The NGT was facilitated by the researcher. The potential for researcher bias or influence was eliminated by following strictly the above highly structured process. The session was recorded and transcribed verbatim to ensure that no data were lost and to provide a documented record of the proceedings. Ethical approval was received from the ethics committee of the University of Malta (proposal no 103/2013). All participants were provided with information regarding the study and consent was obtained before the start of the NGT.

4.5 Results

14 participants accepted the invitation to participate: an executive from the principal public general hospital, a manager from the national Ministry for Health, a service development manager from the allied healthcare professional sector, 2 senior physiotherapists, 3 nursing officers as patient advocates, 3 MRI radiographers, 2 medical physicists, 1 radiologist (see Table 4.2). The final ten optimization related issues in order of decreasing importance as determined by the ranking scores assigned by the participants are shown in Table 4.3.

The rationale for the various participants is shown in Table 4.2.

Participants	Rationale for inclusion as Expert Stakeholder
Executive from the main public general hospital	This participant had expertise on the development of workflows in both healthcare and transport industry.
Manager from the National Ministry for health	As policy maker, this participant had expertise on how care pathways affect service delivery.
Service development manager	This participant had 20 years' experience in developing an allied healthcare service.
Senior Physiotherapists	Senior physiotherapists in a managerial role who had experience in developing similar pathways

	and who are knowledgeable in MRI.
Senior Nursing Officers	Senior Nursing Officers from Orthopaedic, Neurosurgery wards and Neurology wards who were in constant communication with patients undergoing MRI. They were also personally involved in the MRI care pathway.
MRI Radiographers	MRI radiographers working in the private sector and who had similar care pathway in their clinical setting.
Medical Physicists	Senior medical physicists were invited as the care pathway involved quality assurance processes.
Radiologist	Consultant Radiologists are one of the direct stakeholders involved in MRI reporting and communicating with radiographers, physicists and patients.

Table 4. 2 - List of participants and rationale for selection

Rank	ITEMS	REMARKS	RANKING SCORE
1	Safety check at referral stage.	This will ensure that any contraindications related to metallic implants are resolved at an early stage hence eliminating delays on the day of the exam proper (Ferris et al., 2007) . Psychological issues that may affect the procedure are brought to the attention of the MRI radiography team in advance (Grey et al., 2000; Törnqvist et al., 2006). This would permit specific anxiety reduction protocols to be employed.	80
2	Education of referrers	MRI education of referring clinicians is necessary to avoid inappropriate requests and efficient use of MR facilities(Blachar et al., 2006; Lehnert & Bree, 2010).	78
3	Establish pre-determined objective quality criteria for evaluation and monitoring at critical stages of the care pathway	Clinical criteria are a standard process adopted by all health care organizations that espouse the principles of continuous quality improvement (Barnes et al., 1994; McCall, 2002; Busch, 2010).	77
4	Define in terms of effectiveness, safety and	This would ensure that patients receive effective care, in good time and at fair cost (Campbell et al.,	76

	efficiency the meaning of 'quality' for each sub-process of the care pathway.	2000). This should really be a precursor to issue 3.	
5	Early explanation of the procedure to the patient before coming to MRI	An early explanation of the procedure to alleviate anxiety, and identify in advance those patients with claustrophobia is very important (MacKenzie et al., 1995; Bolejko et al., 2008).	69
6	Establish local referral guidelines (appropriateness criteria)	Referral guidelines to assist the referring clinician in choosing the best imaging modality. This issue is a precursor to issue 2 (Rosenthal et al., 2006; Lehnert & Bree, 2010; Blackmore et al., 2011).	66
7	Transparent prioritization guidelines	Transparent prioritization guidelines to ensure urgent cases are scheduled earlier and non-urgent cases are prioritised fairly and in a transparent manner. System must be transparent so that clinicians will not hinder its implementation and so that patients feel that they have been respected (Emery et al., 2009).	65
8	Knowledge of the care pathway by all stakeholders	This would ensure that the care pathway is accepted by all stakeholders and that any subsequent modifications are well understood and accepted by the various stakeholders (Evans-Lacko et al., 2010).	55
9	Patient satisfaction surveys	Patient satisfaction surveys are today considered as an indispensable tool to provide client feedback for further improvement of service quality (Nelson & Niederberger, 1989; Ware, 2003).	50
10	Urgency criteria for diagnostic results following the scan (flagging)	In particular critical incidental findings need to be brought to attention of referring clinicians immediately (Singh et al., 2007; Ferris et al., 2009).	37

Table 4.3 - Final ranking of the ten most important care pathway optimization related issues as determined by the participants.

The group gave a strong affirmative answer when asked if the model pathway as presented by the researchers with the additional 10 issues identified through the NGT was sufficient as the desired future MR care pathway. The resulting MR care pathway is shown in Figure 4.1. The pathway shows the patient's journey from when he/she is referred for an MRI scan up to the follow-up visit to the referrer. The pathway is divided into various sub-processes resulting in sub-process outcomes (indicated with a red '**O**' in the diagram) at which defined quality outcomes (examples shown in light green text boxes) and associated criteria (shown in light blue text box) would need to be documented. For example, the referral form (locally known as request form) is the first piece of information that would need to be appropriately filled to include specific and detailed information about the patient and his/her condition. In addition, it should include confirmation that the patient has no contraindications to MRI, it should pass local referral guidelines and referrer should include additional information such as pain level so that radiologist would be in a better position to prioritize the scan. Which brings us to the next quality outcome that of appropriateness also referred to as justification. Here the radiologist uses professional judgement and transparent prioritization guidelines to vet the request form. The pathway continues sequentially from one outcome to next until all outcomes are fulfilled. For each outcome, the medical imaging department should develop standard operating procedure highlighting all the steps that are required for a high-quality outcome. Each outcome can then be audited independently internally or externally.

The numbers in brackets (1-10) in figure 4.1 refer to the NGT identified issues from Table 4.3 relevant to that particular section of the pathway.

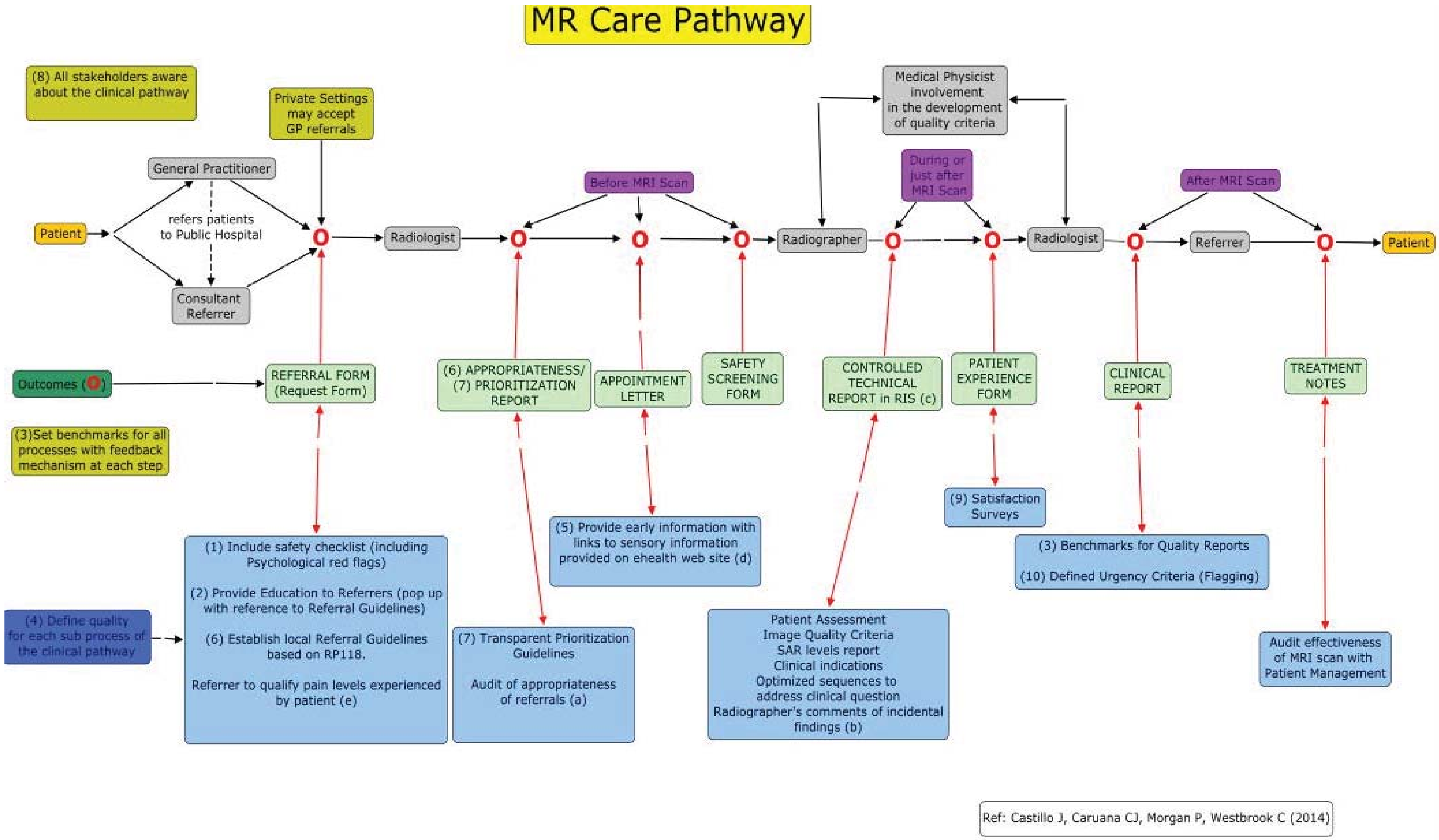


Figure 4.1 - The final MRI Care Pathway

Analysis of qualitative data was carried out using concept maps. Because of how the interconnections are displayed on a concept map, the visual representation of the script offered by concept maps is more analogous to the way we think and to the way we actually discuss concepts in a session like the Nominal Group Technique (Daley, 2004). This process has strength in that the words created by the respondents are used to capture relationships between concepts, and allow structure in the data to emerge based on co-occurrences of words or relational similarities(Jackson & Trochim, 2002; Wheeldon & Faubert, 2009) . Concept mapping was used to condense the data.

Using concept maps the researcher identified additional suggestions which would add further support to the main issues of Table 4.3. These were also incorporated into the care pathway (indicated as (a) – (e) in the figure 4.1):

a) Need for a mechanism to audit the appropriateness of referrals. *"We need to answer the question: has the investigation had an effect on patient management? We are all aware of the high percentage of patients being referred simply because the referrer has no other option - patients insist on an MRI even on occasions when the referrer thinks it is inappropriate" - radiologist*

b) Need to educate radiographers on procedures to follow following incidental findings: *"Although there is an electronic feedback mechanism linking radiographers and radiologists this is not always being utilized owing to the large throughput" - radiographer*

c) Importance of the introduction of a radiographers' technical report: "*Radiographers should issue a written technical report in which they confirm that the quality of the images was sufficient for diagnosis, and that safety criteria have been met and to record any variance from the original care plan. This technical report would form the basis for audits…." - service development manager*

d) The use of social electronic media: *"We should use social electronic media for providing early explanation to patients on what to expect during an MRI scan using social electronic media"-nurse as patient advocate; radiographers*

e) The importance that the referrer qualifies pain levels of patients, claustrophobia, dementia, Parkinson's disease, learning disabilities and others. Protocols would need to be adjusted for patients with these conditions: *"The referrer should qualify the region and level of pain that the patient may be experiencing. This information would be useful for radiographers to plan the procedure so that the most important sequences are acquired first in relation to the clinical question"-nurse as patient advocate*

4.6 Discussion

The MR care pathway describes the tasks performed by the various members of the healthcare team and their interactions with each other and the patient. The aim is to achieve the desired defined quality outcomes at the various sections of the pathway. The group highlighted 10 issues that should be integrated into the initially proposed care pathway. These are listed in order of decreasing importance in Table 4.3. The 'remarks' column in the same table provides further explanation and discussion relative to the literature. It is welcoming to note the importance given by the participants to patient safety, education of referrers and use of quality criteria. MRI is considered to be one of the most dangerous devices in hospital leading to some documented serious accidents. Hand et al. (2013) on behalf of EFOMP recommended the creation of Magnetic Resonance Safety Officer (MRSO) and MR Safety Expert based on the Radiation Protection Safety Officer (RPS) and Medical Physics Expert / Radiation Protection Expert in European legislation targeted to ionising radiation.

The participants identified the importance of involving the referrers at an early stage, insisting that the latter should be made aware about the care pathway, and that they should have access to transparent prioritization guidelines and the current service portfolio. This awareness would reduce individual barriers to the implementation of the pathway (Evans-Lacko et al., 2010).

Two important issues were the importance of referral and quality criteria. The Institute of Medicine round table on quality of care referred to underuse, overuse and misuse of care as safety threats to patients at both the individual and collective level (Institute of Medicine, 2001). Only with compilation, disclosure and evaluation of safety and quality indicators with respect to previously established quality and safety criteria, will the quality of clinical practices be improved (Corrigan, 2005). In addition, evaluation should focus not only on end clinical outcomes but also on intermediate sub-processes (von Korff & Goldberg, 2001; Curtis et al., 2006) as proposed in this study. It is envisaged that audit tools in the form of checklists will be developed to evaluate key intermediate sub-process outcomes (marked with an '**O**' in the diagram) that have major impact on end patient outcomes (Vanhaecht et al., 2006). The group in unison referred to the importance of setting up of quality criteria and that measurements of quality indicators are regularly taken to ensure that quality of the service is assured.

The NGT raised issues that were novel. Most importantly for the radiography profession, the group suggested the introduction of a technical report by radiographers that together with the radiologist diagnostic report would provide a more complete documentation to the referrer, to the MR medical physicist and to hospital management. The technical report should include such technical issues as rationale for any changes of scanning parameters, image quality measures, equipment performance indicators, and presence of artefacts. This would certainly facilitate the successful implementation of the pathway (Greenhalgh et al., 2004; Evans-Lacko et al., 2008).

Another novel theme raised by the patient advocates was the importance of referrers indicating the level of pain experienced by patients. This would permit radiographers to plan a safer and more comfortable procedure for patients. This important suggestion highlights the capacity of healthcare professionals to act on behalf of patients, and the strength of the NGT method in bringing forth previously unknown issues.

Prior information on the MRI procedure for patients should make better use of interactive information technology. Information about what patients should expect during an MRI procedure would be an effective way of improving the workflow and quality of the service. Although such information is not as widely available as is desirable, social media are already being used by patients to liaise with medical practitioners and acquire timely information (Hawn, 2009). In addition, web based clinical decision support systems could assist referring clinicians with respect to referral criteria (Kaushal et al., 2003; Rosenthal et al., 2006).

The production of a prioritized list of issues may be seen as a limitation given that the method involved focusing only on the top 10 issues and setting aside those of lower priority. However, this limitation was addressed by asking all participants to silently generate their own list of issues and thus ensure that all issues have an equal probability of being placed on the discussion agenda. This procedure avoided significant risk of loss of important data when more assertive members of the group dominate effectively excluding the views of others. One can expect a high level of confidence that the group listed the most important items that should be integrated in the pathway. In addition, the process of selection and prioritization ensured that the issues which were most important to the participants received the highest level of attention. Without this mechanism, there would have been the risk that the discussion be dominated by one or two contentious issues.

4.7 Conclusion

This study started from a model of the MR pathway as perceived by the researcher. The pathway was then optimised through a nominal group technique. Care pathways are widely believed to be an important tool for ensuring the delivery of high quality, evidence-based care. The findings indicate that participants attached the highest importance (rank score >70) to safety, referrer education and defining quality criteria. The NGT method also brought forward novel themes in particular the need for a radiographer's technical report and the need for referrers to indicate pain levels of patients. The study has illustrated that a shift in practice for radiographers towards an extended role is in fact already embedded in practice or expected to be the norm. Matching the skills available with the demands of imaging requires a dedicated curriculum which would be in turn central to the delivery of an effective, safe and efficient service. As a result, radiographers need to develop skills over and above those developed during pre- registration education and training. The areas of development identified by participants help identify where priorities should lie for current continuing professional development initiatives for existing staff. In addition, such developments will necessarily also have implications for institutions reviewing the undergraduate curricula in radiography. Opportunities also exist for training and education providers to be proactive in supporting and enabling the widening scope of practice.

The findings of this objective (objective 2 of the study) and the service portfolio (objective 1 of the study) will inform the development of a competence profile for MR radiographers from which the MRI physics learning outcomes could be derived. CPD based on a competence profile is vital for quality professional education and will serve as an assurance that radiographers are working to a set standard. Because profession specific competence profiles for MRI radiographers in Malta are still in a developing phase, the next chapter reports on how the major English-speaking countries are addressing this issue. In particular the next objective (objective 3 of the study) will seek elements of good practice to guide the development of the MRI competence profile to be subsequently developed in objective 4 of the study.

Chapter 5: Objective 3 - to carry out a comparative study of existing competence profiles and qualification and certification frameworks for MRI radiographers in the major English-speaking countries with an emphasis on good practice

5.1 Introduction

This chapter reports the outcomes of surveys on existing competence profiles and qualification and certification frameworks that took place between March and September 2014. The previous two objectives provided a detailed study of what the current MRI service consists of, how it flows and how it is expected to be in year 2020. Whilst the findings of the previous two objectives will define the content of the competence profile, the findings of this survey will assist the researcher in its development and structuring through the identification of elements of good practice within existing competence profiles and qualification and certification frameworks in the major English-speaking countries. The results were accepted for publication in 2017 as 'An international survey of MRI qualification and certification frameworks with an emphasis on identifying elements of good practice, Radiography, 23(1), 8 – 13 (Castillo et al., 2017).

5.2 Background

In Malta, MRI scanners are operated by radiographers registered by the Council of Professions Complimentary to Medicine (CPCM, Malta). Undergraduate radiography programmes often include an MRI component but this training is mostly limited to safety screening and the positioning of patients for common routine procedures. (Portanier Mifsud et al., 2014) Following qualification, entry level radiographers perform, under supervision, routine non-complex procedures that do not require advanced protocol modification with respect to the individual patient or pathology. Further training may be acquired through hands-on practice provided in-house and continuing professional development activities organised by the Malta MR Radiographers Group (MMRRG) and Society of Radiographers (SRM, Malta). Concern has been expressed that such activities are rarely assessed formally and may be insufficient to confer sufficient expertise.(Westbrook & Talbot, 2009; Ribeiro et al., 2010; Moberg; Alsharif et al., 2017; Westbrook, 2017)

Interestingly, in Malta, in 2003 a legal framework for a specialist register within the CPCM was established through the Maltese Health Care Professions Act (Ministry for Justice Culture and Local Government, 2003), however, the framework for MRI certification as a specialty and based on an MRI radiographer competence profile has yet to be established. Inclusion of MRI in this specialist register would be important to Maltese MRI radiographers as it would establish a clear pathway for career advancement.

In 2012, the European Federation of Radiographer Societies published a position paper (in response to the Electromagnetic Fields Directive 2004/40/EC)(European Federation of Radiographer Societies, 2012) stating that it aims to develop requirements for MRI competences, qualification and certification. However, to date no such European MRI frameworks have been published. In the absence of a European competence profile or education and certification frameworks the major English-speaking countries (New Zealand, Australia, United States, Canada, United Kingdom and Ireland) were surveyed with the purpose of identifying elements of good practice in the development of competence profiles and the possible setting up of a national qualification and certification framework.

5.3 Purpose

The researcher sought to carry out a comparative study of existing competence profiles and qualification and certification frameworks for MRI radiographers in the major English-speaking countries with an emphasis on good practice.

5.4 Methodology

The study was conducted using a cross-sectional qualitative documentary survey (Shaw et al., 2004) of competence profiles and MRI qualification and certification documents from the major English speaking countries. These countries were chosen as educational provision and/or role development is relatively advanced and related documentation often well-developed and easily available (Cowling, 2008). Documentary analysis is a research strategy often used in qualitative research. (Fitzgerald, 2007; Momeni et al., 2008; Ahmed, 2010; Blundell EG, 2012). Advantages of documentary analysis are that documents provide records of present frameworks and future proposals. A further strength of documentary evidence is the fact that records tend to be unbiased as the documents are written usually for other purposes i.e., the researcher is not in a position to bias the authors. Another advantage is the fact that the researcher can obtain data without being present in the field (Ahmed, 2010). In addition, documents are often available in the public domain and ethical issues are rarely problematic. Documents for this objective were retrieved from official websites of regulatory authorities, national and international professional societies, universities and accreditation institutions. As recommended by Scott (2014) and Ahmed (2010) each document was checked for authenticity, credibility, representativeness and meaning. Authenticity refers to whether the evidence is genuine and from an implacable source; representativeness refers to whether the documents consulted are representative of the situation in the particular country, and meaning refers to whether the evidence is clear and comprehensible. The main limitations of documentary analysis are that documents may sometimes not be sufficiently current (Caruana & Plasek, 2006b) or miss some information (Ahmed, 2010) and that the researcher may extract data that best supports his/her own interpretation of the data (Appleton & Cowley, 1997; Shaw et al., 2004). The effect of the latter limitation was reduced by having a second independent researcher to analyse the documents. To reduce the effect of the former limitation, the websites were regularly checked for updates and findings were double checked by triangulation with information solicited through a web-based questionnaire amongst a select group of MRI expert radiographers (n=39) from the countries involved. The experts chosen were members of the ISMRM/SMRT who were involved in MRI education and/or MRI advanced practice in their respective countries. When the level of consensus between the two sources of data was considered insufficient the issue was clarified further via direct email communication. The questionnaire included 18 close-ended and 16 open-ended questions on competence profiles, MRI qualifications, certification, registration and role of regulatory organisations. The questions were structured to strictly reflect the research objectives and validated by the ABoE. Piloting of the questionnaire was carried out with a small international group of MR radiographers since it was intended for international participation. The web based questionnaire can be viewed in Appendix E. All responses were anonymised by setting the software to hide the IP addresses. To reduce the effect of researcher's bias the final interpretation was resent to a second group of independent MRI experts (one from each of the countries involved) for validation. Approval to carry out this objective was obtained from the University of Malta Research Ethics Committee (proposal no 104/2013).

5.5 Results

The documentary data analysis focused on the following categories: competence profiles, MRI qualifications (including programme accreditation), certification and registration. Key sentences/phrases or statements which were identified as descriptors related to each of the above categories were highlighted in the text. Relevant data were subsequently inserted into the corresponding categories and checked for levels of hierarchy, interconnections and repetition. The websites were regularly checked for any updates / reviews and whenever new information was published this was analyzed and the grid modified as needed. A summary of the data can be found in Table 5.1. Table 5.2 gives details of the types of institutions offering MRI programmes and details of accreditation. The decision whether a particular practice constitutes good practice or otherwise was based on whether the particular practice is consonant with the spirit of the quality oriented recommendations of the EQF (particularly Annex III which deals specifically with quality (European Commission, 2008).

Country	Competence Profile	Qualification	Certification	Registration	Notes
Australia	No national MRI competence profile exists.	Post-graduate diploma and Masters courses in MRI are available.	No formal certification specific to MRI is available.	Entry-level radiographers are registered by the Medical Radiation Practice Board (MRPB) following a degree in radiography. The Australian Institute of Radiography (AIR) maintains a non-compulsory register for MRI radiographers. Two registration levels are available: Level 1 is based on a written test; Level 2 requires clinical experience and CPD portfolio. PGDip or MSc not mandatory for registration.	AIR has published generic professional standards referenced to the Australian Qualification Framework. MRPB issued a separate inventory of 'capability statements' very similar to AIR but not specific to MRI.

New Zealand	National MRI competence profile adapted from a competence profile developed by the Medical Radiation Practice Board of Australia (but which has however not been adopted nationally by Australia itself). The profile is widely used as a curriculum blueprint by tertiary educational institutions. Individual practitioners use the standards to guide their professional development.	Post-graduate diploma programme in MRI is available.	Requirements for MRI certification are a BSc in Medical imaging and PGDip in MRI combined with MRI experience. However, those who do not have a PGDip in MRI can submit any MRI qualification or any qualification and experience in another appropriate imaging modality but must sit and pass a specific Board registration examination assessment (REA) in MRI. If MRI qualification does not consist of a clinical component one has to complete 3360 hours of clinical MRI practice before doing REA.	MRI technologists are registered by the Medical Radiation Technologists Board (MRTB). Two levels of MRI registration are available -Trainee and Full. Registration is compulsory and so is annual re-registration.	Ongoing debate whether qualification and certification framework should be changed – effectively to lower the requirements to allow more radiographers to practise MRI.

US	Practice standards were developed by the American Society of Radiologic Technologists (ASRT). These are not nationally binding.	Accredited MRI specific undergraduate academic programs available.	MRI certification follows a certification examination run by state, ARRT or ARMRIT. Additional certification may be required for specific MRI applications such as cardiac MRI.	There are two pathways to acquire registration: ‘Post-primary’ available only to ‘radiologic technologists’, and ‘primary’ open to non-radiological technologists. Once MRI registered Registration must be maintained through a CPD portfolio.	Detailed MRI syllabus developed by ASRT, SMRT and AEIRS is available.
Canada	CAMRT provides a national MRI specific competence profile for entry level MRI practices but not for advanced practice. A new competence profile will be effected in 2018.	MRI Diploma programmes at institutes of technology or college are available. CAMRT recognises two levels of MRI certification. ‘Discipline 1’ (only in Alberta) and ‘Discipline 2’ open to students who have completed a medical imaging course.	Radiation technologists are expected to have completed an accredited MRI programme from an institute of technology or college and enroll in MRI CPD programs to obtain and maintain certification.	Registration with CAMRT is based on a national certification examination which is based on a national competence profile. MRTechnologists are expected to enroll in CPD.	Although no MRI competence profile has been developed for experienced technologists, the CAMRT has introduced ‘Best Practice Guidelines’ best practice guidelines that includes MRI safety.
UK	Skills for Health had developed a competence profile for MRI.	Several post-graduate programmes (MSc and PGDip) in MRI are available.	No formal certification specific to MRI is available.	Radiographers are registered by the Health Professions Council. There is no separate registration for MRI radiographers and post-graduate qualification or	A generic education and career framework developed by the SOR serves as a guideline for professional development at various levels of expertise,

				certification in MRI is not mandatory for employment purposes. Selected radiographers are asked to submit a CPD portfolio.	however none specific to MRI.
Ireland	No detailed MRI specific competence profile exist.	Post-graduate courses (MSc and PGDip) in MRI are available.	No formal certification specific to MRI is available.	Entry radiographers are registered by the radiography registration board. There is no separate registration for MRI radiographers. No MRI qualification or certification is mandated by law but qualification is highly desirable and a requirement for the post of 'MRI clinical specialist'. Selected radiographers are asked to submit a portfolio of evidence showing they have attained 60 CPD credits over 24 months.	'Guidelines on Best Practice in MRI' have been published by the Irish Institute of Radiography and Radiation Therapy (IIRRT) and includes responsibilities expected from the clinical specialist and the MRI radiographer.

Table 5. 1 - Key findings from the analysis of documents and triangulation questionnaire.

Country	Institutions offering MRI programmes	Accreditation Body
Australia	Only University of Queensland offers MRI specific Masters Degree programme. Charles Sturt University and University of Sydney offer Master Degree programmes in medical imaging sciences (with PGDip in MRI – exit point only).	Medical Radiation Practice Accreditation Committee within the Medical Radiation Practice Board of Australia (MRPB)
New Zealand	Only University of Auckland offers an MRI programme (PGDip).	Regulatory Authority for Medical Radiation Technologists under the auspices of the Ministry of Health
US	Universities and colleges	Joint Review Commission on Education in Radiologic Technology (JRCERT) or by other accreditors that are in turn accredited by the Council for Higher Education Accreditation (CHEA) or the US Department of Education (USDE).
Canada	Institutes of technology and colleges offers 'Discipline 1' and 'Discipline 2' diploma programmes	Consortium of national and provincial organizations, colleges and universities ensures requirements set by the Canadian Association of Medical Radiological Technologists (CAMRT) and Canadian Medical Association.
UK	Several universities offer MRI programmes (both PGDip and MSc).	College of Radiographers – Approval and Accreditation Board.(The Society of Radiographers, 2016)
Ireland	University College Dublin (UCD) and Trinity College Dublin offer postgraduate education (both PGDip and MSc) in MRI.	Only the UCD programme is accredited by the IIRRT.

Table 5. 2 - Types of institutions offering MRI programmes and methods of programme accreditation

PGDip and Masters programme accreditation varies from one country to another and may be provided by a national professional society, health ministry, university, or national accreditation agency. University or college based MRI programmes in Canada, New Zealand, Australia and the US are externally accredited by national accreditation bodies whilst in the case of the UK and Ireland external accreditation is provided by professional societies. The pre-requisite qualification to enter PGDip or Masters education programmes in MRI is generally a university undergraduate degree or a higher undergraduate diploma in radiography. Clinical entry requirements vary widely with some institutions asking for post-registration MRI experience, whilst others (e.g., New Zealand, Ireland) do not and include a clinical component in the programme proper. In all countries, teaching, supervision and assessment is shared between university tutors, clinical instructors and qualified MRI radiographers. The assessment includes a variable assortment of portfolios of evidence, assignments, examinations and dissertation.

Due to the diversity in competence profiles, certification frameworks and registration the findings will be presented by country.

Australia

To practice radiography in Australia, one must graduate from an accredited university programme in general radiography and then enroll in 48 weeks of clinical supervised practice. Although undergraduate degree courses cover basic MRI physics, only limited clinical MRI training is provided.(Australian Institute of Radiography, 2010) As a result, the Australian Institute of Radiography (AIR) recommends that MRI practitioners undergo specific training and supervised clinical experience prior to assuming responsibility for patient scanning. The AIR accredits two levels of post-qualification MRI certification: level 1 (basic) and level 2 (advanced) (Australian Institute of Radiography, 2010, 2014a). Although AIR maintains a register of radiographers certified at both levels, this is voluntary and in practice no qualification or certification is required to practice (see summary in Table 5.1). Public hospitals often require AIR certification whereas private clinics do not (Strugnell, 2006). In the absence of a national MRI-specific competence profile, some hospitals have developed their own. In 2014, AIR launched an advanced practitioner pathway that is referenced to the Australian Qualification Framework and which incorporates the professional practice standards revised in 2013 (Australian Institute of Radiography, 2013, 2014b). However, the listed competences are generic and not modality specific. The MRPBA also issued an inventory of knowledge, skills and 'attributes' necessary for practice but these are at entry level and are not modality specific (Medical Radiation Practice Board of Australia, 2013).

New Zealand

The "scope of practice and related qualifications" of the Medical Radiation Technologists Board (MRTB) of New Zealand, states that in order to be certified and registered to work in MRI, radiographers must have a first degree in radiography/medical imaging and a university-based post-graduate diploma in MRI from a New Zealand tertiary education provider that is accredited and monitored by the MRTB (New Zealand Medical Radiation Technologists Board, 2013b). However, there is an alternative pathway for registration (New Zealand Medical Radiation Technologists Board, 2013b) and if the technologist does not have MRI experience, a practice period of 3360 hours clinical MRI practice is required before undergoing the REA. The listing in the MRI register is compulsory and all radiographers must take part in a CPD programme. A national competence profile is also available and is used to provide guidelines for tertiary institutions that are providing a programme in MRI technology, to assist in the development of curricula and to monitor programme delivery. At the moment of writing this report, MRTB is changing its competence profile. The old version included three levels of increased complexity (New Zealand Medical Radiation Technologists Board, 2013a) which were Skill level 1 ("can perform some parts of the skill satisfactorily but requires guidance and/or supervision to perform the entire skill"), Skill level of 2 ("can perform the skill satisfactorily but requires guidance and/or supervision") requires only the acquisition of a small subset of competences and skill level 3 ("can perform the skill satisfactorily without guidance and/or supervision") requires the acquisition of the great majority of competences. The competence profile is reviewed every three years and until and inclusive of 2013, reviews focused on revisions of the content of the competence standards required for each speciality, with the design framework for the expression of the standards remaining essentially the same format as described above.

In 2016 the MRTB has undertaken a broader review of the competence framework for medical imaging/radiation therapy healthcare professionals to revise both the design and content of the competence standards (New Zealand Medical Radiation Technologists Board, 2016). Through a consultation process amongst healthcare professionals, including radiologists, radiographers and educators, MRTB has sought to integrate all competence profiles of all specialities through the adoption of an overarching framework based on the principles of flexibility and versatility, and that is relevant to a variety of stakeholders. It now includes 4 generic domains which are common to all specialities and 1 specific domain. The MRI domain is made up of 5 key activities which cover clinical applications, quality assurance, safety management, evaluation of images, and consultation with other professions. In the revised version, MRTB has dropped the 3 skill levels and expressed the competences only at entry-level but stating that that all MRI radiographers are expected to successively build on these competence standards to levels expected of experienced practitioners. This experience level is however not defined as in previous version and the specific statements are worded broadly presumably to allow for universal applicability across a variety of practice settings. In order to provide a level of assessment the competence profile now includes a number of mandatory actions for each key competence. The revised competence framework which was validated by only 5% of the invited participants has been adapted from and aligned with the *Professional Capabilities for Medical Radiation Practice document* of the Medical Radiation Practice Board of Australia (MRPBA) (New Zealand Medical Radiation Technologists Board, 2017). This is expected to strengthen the two Boards under the provisions of the Trans-Tasman Mutual Recognition Act. Having similarly articulated competence standards allows for a more seamless transition of medical imaging/radiation therapy healthcare professionals wanting to practise in either of the two countries. The competence profile is not written in the KSC format and is not referenced to a national qualification framework. Annual re-certification is required and 10% of radiographers are asked to submit a CPD portfolio as part of the Board's audit process. Further details can be found in Table 5.1.

United States

Radiologic and MRI 'technologists' must be registered in some states, but requirements vary by state. To become registered, technologists must graduate from an accredited academic program and must pass a certification exam from the state or from the American Registry of Radiologic Technologists (ARRT). For the individual who wishes to be certified in MRI, two pathways are available (see Table 5.1). MRI certification can be obtained by sitting an examination organised either by the ARRT or the American Registry of MRI Technologists (ARMRIT), after successfully following an accredited academic programme in MRI. The content of both the ARMRIT and ARRT certification examinations are based on a job analysis study involving a large sample of MRI technologists (American Registry of MRI Technologists, 2015; American Registry of Radiologic Technologists, 2015b). The resultant task inventory contains a list of 51 skills and 78 procedures that MRI technologists are expected to carry out 40% of the time (American Registry of Radiologic Technologists, 2015c). In a separate document, the ARRT identified the 4 main categories (key activities) together with the knowledge areas (list of topics) which underlie the performance of the tasks listed in the inventory. The researcher is of the opinion that if these two documents were merged it would result in a national competence profile that would indeed lead to a national curriculum. Indeed, they were used by a multiorganization collaboration process which included the American Society of Radiologic Technologists (ASRT), the Section of Magnetic Resonance Technologists (ISMRM-SMRT), and the Association of Educators in Imaging and Radiologic Sciences (AEIRS) to develop a national MRI curriculum designed to address the didactic and clinical competences as required by ARRT (ASRT et al., 2008). This curriculum which is expressed in a learning objectives format has not been updated since 2008.

Following certification, the technologist maintains annual registration by submitting a CPD portfolio based on 24 credits accrued over 2 years. Additional certification by the supervising physician may be required for specific MRI applications such as Cardiac MRI (Woodard et al., 2006). From January 1, 2015, all primary pathway candidates for certification in MRI were required to earn an academic degree for certification (Table 5.1) (American Registry of Radiologic Technologists, 2015a).

Practice standards in MRI were also established by the ASRT for judging the quality of practice, service and education. These standards are divided into six sections and include the scope of practice, clinical performance, quality performance, professional performance and advice on how the standard should be interpreted. However, State statute, regulation or lawful community custom may dictate practice parameters which could conflict with these standards and state or local statutes or regulations. In such situations, the state or local statutes or regulations supersede the ASRT standards. The standards do not include what knowledge is required and only include a list of generic and modality specific skills.

Canada

In January 2014, the Canadian Association of Medical Radiologic Technologists (CAMRT) published a new MRI competence profile to be implemented in the May 2018 certification exams for entry level MRI technologist (Canadian Association of Medical Radiation Technologists, 2014). The competence profile which is typically reviewed every five years by a review committee, followed by consultation with regulators, education programs, practitioners and service department heads / managers also serves as a blueprint for the development of curriculum of accredited education programs. The current competence profile is made up of 12 modules, 6 of which refer to clinical applications, 1 module refer to core competences and the other 5 modules refer to quality management, MRI safety, professional practice and patient management. An analysis of the competence profile format indicate that it is structured as a list of skills and knowledge statements all grouped together. The profile does not distinguish between statements that are expected by entry level technologists and those who are more experienced.

The CAMRT website indicates that a new competence profile will be published in 2018. In this version, the modules will be reduced to 5 namely professional practice, patient management, health and safety, operation of equipment and procedure management. Competences which are similar to several modules are grouped in 4 appendices namely patient interactions, common pathologies, imaging procedures, and pharmaceuticals. Despite this update there were no new competences and it is not structured in the knowledge, skills and competence format.

MRI certification is mandatory and awarded by CAMRT based on a national certification exam after the candidate completes an accredited educational program in MRI. CAMRT recognises two levels of MRI diploma programmes and students are eligible to work as MRI technologists anywhere in Canada if they pass the CAMRT national exam. In the provinces of Ontario, Nova Scotia, and Alberta, one must also belong to the provincial regulatory college (Alberta College of Medical Diagnistic and Therapeutic Technologists, 2015; College of Medical Radiation Technologists of Ontario, 2015; Nova Scotia Association of Medical Radiation Technologists, 2015). Although CPD is not mandatory for re-certification Canadian MRI technologists are expected to enroll in CPD programs. CAMRT has also introduced 'Best Practice Guidelines' to assist experienced practitioner during decision making for specific clinical circumstances including MRI safety (see summary in Table 5.1) (Canadian Association of Medical Radiation Technologists, 2015).

United Kingdom

In the UK, Skills for Health, which is an independent council within the National Health Service and representing a range of healthcare employers, developed a national MRI competence profile ('occupational standards') which cover key MRI activities (Skills for Health, 2007, 2009). These standards are not mandatory and are not expressed in the knowledge, skills, and competences format required by the European Qualification Framework (EQF) (European Commission, 2008). Although the Society of Radiographers has published an education and career framework (The Society of Radiographers, 2013) to serve as a guideline for generic professional development which includes a list of outcomes to be demonstrated at various levels of expertise, the document falls short of defining the required specific knowledge, skills, and competences and does not reference to the EQF. The UK has mandatory registration for all radiographers qualified in general radiography via the Health Care Professions Council (HCPC) with a mandatory biennial re-registration based on the presentation of a portfolio of CPD activities within the radiographer's scope of practice. This means that a selection of radiographers working in MRI would need to present evidence of their experience in MRI (see summary in Table 5.1) (Health and Care Professional Council, 2011).

Ireland

To practice radiography in Ireland one must graduate from an accredited university and register with the radiographers' registration board of the Health & Social Care Professionals Council (CORU). The Irish Institute of Radiography and Radiation Therapy (IIRRT) has published a 'Guidelines on Best Practice' document (Irish Institute of Radiography and Radiation Therapy, 2014) which recommends that to work in MRI a radiographer should either undertake a course of postgraduate education in MRI approved by the IIRRT or be considered by the Radiography Service Manager in consultation with the MRI clinical specialist radiographer (CSR). The latter must have at least 6 years' experience in MRI and possess a postgraduate qualification in MRI at EQF level 7.(Irish Institute of Radiography and Radiation Therapy, 2014) The CSR is responsible for day-to-day responsibility of the MRI department including quality assurance, procurement and development of imaging protocols. In the absence of the supervising consultant radiologist the MRI CSR is deemed the responsible person for all patient/staff safety issues.

The 'Guidelines on Best Practice' document describes a comprehensive list of professional responsibilities that are required by the MRI radiographer to mainly ensure safety of the patient and staff within the MRI environment (Irish Institute of Radiography and Radiation Therapy, 2014) however this is not written in the knowledge, skills and competence format and again it is not referenced to the European Qualification Framework (European Commission, 2008). Ireland has mandatory re-registration for all radiographers which include the presentation of a portfolio covering 60 CPD activities within a 24-month cycle and within the radiographer's actual scope of practice which could be MRI (see summary in Table 5.1) (Health and Social Care Professionals Council, 2016).

5.6 Discussion

No other study on competence profiles and MRI qualification and certification framework was found in the literature. This objective highlights similarities and differences in the qualification and certification frameworks for MRI radiographers in the major English-speaking countries and whether these are based on a competence profile. Canada and New Zealand have mandatory certification and registration based on a national MRI-specific competence profile and a higher education qualification obtained from an accredited centre. A similar trend towards higher qualification has been followed in the US since January 2015 but the examination is primarily based on a task inventory. Practice standards have been developed by the ASRT but these are not binding across the country. In Australia, the AIR offers a certification and registration pathway referenced to a national qualification framework (Australian Institute of Radiography, 2014b) and to a set of generic professional practices standards. However, these standards are not mandatory for employment. The UK and Ireland do not offer MRI specific certification and registration, but radiographers are required to maintain a CPD portfolio that reflects their actual scope of practice which could be MRI. The lack of mandatory assessment in the UK has raised concerns regarding safety (Westbrook & Talbot, 2009). In Ireland, a postgraduate qualification and number of years of experience is mandatory for the post of 'MRI clinical specialist'. The provision of mandatory postgraduate qualification in MRI, from an accredited higher education institution (as opposed to informal non-formally assessed training), together with a specified number of years of supervised experience in MRI as pre-requisites to certification would be considered elements of good practice. If such postgraduate qualifications have a well-defined scope they would facilitate comparability and hence may contribute to improved mobility across national, regional, and international boundaries (The European Centre for the Development of Vocational Training, 2014). Programmes based on a national competence profile that is in turn developed on an analysis of practice (American Registry of Radiologic Technologists, 2015b), is another important element of good practice. National competence profiles can also be used by MR department managers to support the development of their staff and to assist them during job interviews. For the individual MRI professional, the profile can be used as a self-assessment tool to gauge own level of professional development. All the national competence profiles are developed for certification purpose and as a guide for curriculum development and the utilization of a clinical portfolio as in New Zealand, the UK, Ireland and Australia would ensure that assessment and certification be based on evidence (McMullan et al., 2003). Another element of good practice is to ensure that the competence profile is referenced to a national qualification framework. The findings indicate that this was only proposed by the AIR (Australia) and surprisingly was not adopted by the Australian regulatory board. In the case of Europe, mobility may be enhanced if national qualification and certification frameworks are based on competence profiles and referenced to European frameworks such as the EQF. This comparability of competences to ensure mobility was noted by the Australian and New Zealand registration boards and is certainly an element of good practice. Certification would ideally be carried out by a nationally accredited professional or regulatory body and would provide a statement of fitness to practice at a particular level of expertise. A separate MRI register maintained by a regulatory body as in the US, Canada, and New Zealand is another element of good practice.

It was noted that there were no documents from regulatory boards regarding PET/MRI. This hybrid modality is still in its infancy and the only document that the researcher came across was an initial set of recommendations by the Section of Magnetic Resonance Technologists of the Society of Nuclear Medicine and Molecular Imaging Technologists (Gilmore et al., 2013). Further research is required in this area.

5.7 Conclusion

This objective has analysed competence profiles and MRI qualification and certification frameworks in the major English-speaking countries and identified elements of good practice. Some countries have well established frameworks whilst in others such frameworks are being developed and are works in progress. Continuous update of competence profiles is crucial, since service portfolios change with time in response to the ever-changing needs of the healthcare system. Therefore, it should be noted that the practices presented and discussed in this chapter are a snapshot at one particular moment in time.

The next chapter reports on the development of such a competence profile for Maltese MR Radiographers. The competence profile is a critical objective out of which the researcher would then develop the inventory of biomedical physics learning outcomes.

Chapter 6: Objective 4 - to develop and validate a competence profile, that would be necessary and sufficient to deliver the forecasted 2020 MR service portfolio and optimised care pathway developed in Objectives 1 and 2 and inspired by international competence profiles identified in Objective 3.

6.1 Introduction

This chapter reports on the development and validation of a competence profile for MRI radiographers in Malta that would be necessary and sufficient to deliver the forecasted MR service portfolio and optimized care pathway developed in Chapter 3 and 4 respectively. The competence profile was inspired by elements of good practice from the competence profiles identified in the previous chapter. The study was presented at ECR, Vienna as an electronic poster titled 'Validation of a competence profile for MR radiographers using a formal research process' in March 2016 (Castillo et al., 2016). *The presentation was awarded the best presentation prize in the Radiographer's section.*

6.2 Background

In the European Qualifications Framework (EQF) competence is defined in terms of 'responsibility and autonomy'. Thus, a competence profile can be defined as a list of key responsibilities or activities for a given class of health care professionals.

The Higher Education Network for Radiography in Europe (HENRE) has developed an inventory of agreed generic and subject specific competences for the first cycle of Radiography (diagnostic and therapy) education (Challen, 2008; Akimoto et al., 2009). The first cycle HENRE inventory indicates that it is highly unlikely that entry level radiographers would have received formal education for carrying out investigations carried out in a MR unit. Studies in MR education show concern regarding the insufficient education of MR practitioners and indeed most of the training carried out in MR clinical settings is informal, delivered in-house and rarely assessed (Westbrook & Talbot, 2009; Moberg; Opoku et al., 2013; Westbrook, 2017). In 2017, EFRS has published an inventory of level 7 learning outcomes to serve as point of reference for educational institutions and radiography professional bodies to benchmark radiography educational programmes at EQF Level 7 (European Federation of Radiographer Societies, 2017). Although, this document may also serve to promote mobility and to facilitate and encourage lifelong learning, the competence inventory does not delineate the specific responsibilities that can be applied directly to magnetic resonance (MR). This means that the latter would still need to be developed by MRI management.

Competence profiles are valuable to students, faculty, and employers. Such profiles help students form accurate perceptions of, and to be motivated to pursue a field of study. Faculty can use profiles to clarify practices in their disciplines, design appropriate educational materials and instruction, and link other disciplines to their own. Employers can use these profiles to communicate their expectations to educators and to guide professional development for employees. Program evaluators can use competence profiles to link learning outcomes to long-term skills and behaviours (Davis et al., 2005).

6.3 Purpose

An initial literature search indicated that no agreed pan European competence profile specific for MR has yet been developed. Owing to the limited time for CPD available and hence the difficulty of covering all the knowledge, skills and competences required for the full range of MR techniques available today, it is important that competence profiles are context specific. The research question underpinning the focus of this objective was therefore: What competences do MR radiographers need to have in order to deliver the MR service portfolio and optimised care pathway to be delivered by 2020 in Malta as developed in the first two objectives of the study?

6.4 Methodology

The results of the preceding objectives were utilized to develop the competence profile. During the write up of the competence profile, care was taken to ensure that elements of good practice regarding competence profiles identified in objective 3 and criteria for a quality competence profile as discussed by Davis and Beyerlein (2006) were adhered to. These characteristics are:

Comprehensive – addresses all key areas important to the profession or discipline

Conciseness – provides a snapshot of key responsibilities

Distinctness – statements are non-overlapping

Organized – statements are ordered or grouped for deeper meaning

Action Orientation – statements identify observable actions

Compelling – elements inspire development and respect.

The initial blueprint of the draft MR competence profile was reviewed by the ABoE. The draft competence profile was regarded as would be sufficient for the delivery of the 2020 service profile and optimised care pathway. It was also decided that although the results of the first objective indicated that there was insufficient consensus regarding 3T MRI, recent developments were making the inclusion of such a competence desirable (Schmitt et al., 2004; Alvarez-Linera, 2008; Blamire, 2008). A competence which includes 3T MRI was therefore included. Similar decisions were taken regarding participation in research and prostate screening. The resulting competence profile was then validated with a panel of MR stakeholders using a Delphi process. Seven participants representing the radiographers' and radiology societies, the public and private sector radiology departments, the Faculty of Health Sciences of the University of Malta, and Medical Physics Department were invited to participate. The intention was to create a balanced representation of the stakeholders with different professional backgrounds in clinical, management, academic, and professional societies and who are involved or collaborate in magnetic resonance imaging practice and education.

The web-based Delphi method chosen for this study made it possible for a panel of busy MR experts to contribute to the validation of the competence profile. Although a face-to-face nominal group technique or focus groups would also have been suitable, resource and time constraints precluded the possibility of these options. In addition, the Delphi method has the advantage that it promotes panel member contributions free of the influences of personal styles and statuses impacting face-to-face techniques. A disadvantage of this method is that the researcher relies upon his personal interpretation without the opportunity for immediate clarification that would be possible in a face-to-face meeting. This disadvantage was reduced by carrying out separate email discussions with individual participants between phase 1 and phase 2 of the Delphi technique when clarification was necessary. This produced additional qualitative data that enhanced the development of the competence profile.

A web based questionnaire, showing a list of MR competences with an attached 6-level Likert scale, was piloted by two additional radiographers who practice MR imaging (one Maltese and one non-Maltese) and who are in possession of a higher qualification in MR imaging at EQF level 7 (Master's degree). Their remit was to assess each statement for appropriateness and accuracy, for any overlap with other statements and for a level of content detail that was meaningful even to an outside reviewer. The final list of 43 competence statements grouped under seven key activities is shown in Table 6.1.

A cover letter explaining the PhD work so far and a link to the web based Delphi survey was sent to each of the experts via email. The participants were asked to register their level of agreement regarding the importance of each competence statement using the following Likert scale:1 = completely disagree, 2 = generally disagree, 3 = slightly disagree, 4 = slightly agree, 5 = generally agree, 6 = completely agree. No neutral ('neither agree nor disagree') point was used as suggested by Beaudin (1999) but each participant was given the option to comment on or modify the statement. The measures of level of agreement with the competence statement and level of consensus among the participants were the median and IQR respectively (Rayens & Hahn, 2000; Hsu & Sandford, 2007). Email correspondence was carried out between rounds to discuss further modifications to statements that either achieved too low a median level (4 and less), or too low consensus (IQR higher than 1) or where the comments from the participants showed that the statements could be improved further. In such cases attempts were made to improve the competence statements to increase the level of acceptance with the proviso that the level of consensus did not become unacceptably low (i.e., IQR was never allowed to exceed 1.0). Ethical approval was received from the ethics committee of the University of Malta (proposal no 178/2014).

6.5 Results

All participants agreed to participate in the study. The competence profile together with the results of the first round (Median1, IQR1) and second round (Median2, IQR2) of the Delphi are shown in Table 6.1. The competences are categorised under six Key Activity areas of the radiographer which are Image Acquisition (IA), Education (E), Quality Assurance (QA); Safety and Risk Management (SRM), Service Unit Management (SUM), Facility Management (FM) and Research (R). Modifications in competence statements in the second round designed to improve the level of acceptance and/or level of consensus or the wording of the competence statements to reflect participant feedback from the first round are shown in italics.

In the first round of the Delphi all statements except one (IA3) achieved the desired level of acceptance (≥ 5). Statement IA3 achieved an acceptance level of only 4. With regards to level of consensus, 38 statements (including IA3) achieved an IQR ≤ 1.0, however 5 (IA16, IA19, IA20, E3,FM3) statements had an IQR higher than 1.0. Six additional statements required rewording based on the qualitative analysis of the respondents' comments.

The 12 statements which did not achieve the desired level of acceptance or consensus or required rewording and a proposed revision were sent to each participant for further comments and clarifications. The returned responses were considered and the 12 revised statements were sent to all the participants for a second Delphi round. In the second round all revised statements achieved the target level of agreement and consensus, except for 3 statements (IA16, IA20 and E3) which retained an unacceptable level of consensus. This was attributed to a difference of opinion between radiography and radiology participants. In two further competence statements (QA4 and SRM2) it was noted that while the level of acceptance remained high there was a reduction in the level of consensus although the IQR still satisfied the condition IQR ≤ 1.0. Further analysis showed that the disagreement was the result of a difference in opinion between the radiography and medical physics participants. However following consultation with the ABoE the revised text was retained in these two cases since the revised text was more in consonance with the multi-stakeholder approach adopted in this thesis and the IQR was still ≤ 1.0.

Delphi studies based on 6 point Likert scales are often stopped when an IQR of 1.0 or less is attained on the greater majority of the probed statements (Bailie, 2011;

Giannarou & Zervas, 2014) (von der Gracht, 2008). Since the probability of achieving a level of consensus ≤ 1.0 on statements IA16, IA20 and E3 was low, the Delphi was stopped at this point.

Competence Code	Competence Statement	Median1	IQR1	Median2	IQR2
Image Acquisition refers to the use of knowledge of anatomy, pathology and physics to produce images of high diagnostic effectiveness. The MR radiographer uses devices and optimizes imaging parameters to acquire the best possible images for interpretation.					
IA1.	Assumes responsibility for the planning and execution of Neurology MR including Diffusion Weighted Imaging, Magnetic Resonance Angiography, MR tractography, MR Neurography. *Planning for Deep Brain Stimulation is carried out under neurosurgeon's supervision.*	5.0	0.5	6.0	1.0
IA2.	Assumes responsibility for the planning and execution of Body MR including Diffusion Weighted Imaging, Magnetic Resonance Angiography and MR Enterography.	5.0	0.5		
IA3.	Assumes responsibility for the planning and execution of Breast MR. *MR guided biopsy of the breast is planned under supervision of breast specialist.*	4.0	1.0	6.0	0.0
IA4.	Assumes responsibility for the planning and execution of Musculoskeletal MR including MR arthrography and e.g., patellar tracking).	5.0	0.0		
IA5.	Assumes responsibility for the planning and execution of MR Cholangiopancreatography (MRCP), MR Liver, MR Pancreas and MR Liver Elastography.	5.0	0.5		
IA6.	Assumes responsibility for the planning and execution of MR male pelvis including prostate and rectum.	5.0	0.5		
IA7.	Assumes responsibility for the planning and execution of MR female pelvis including uterus, cervix, and ovaries.	5.0	0.5		
IA8.	Assumes responsibility for the planning and execution of Paediatric MR.	5.0	0.5		
IA9.	*Shares responsibility* for the planning and execution of MR sequences requested for the assessment of change in tumour burden as a measure of treatment response or tumour progression.	5.0	0.0	6.0	0.5
IA10.	*Shares responsibility* for the planning and execution of MR Cardiac procedures *under supervision of a cardiac specialist.*	5.0	1.0	5.0	1.0
IA11.	Assumes responsibility for the planning and execution of vascular MR.	5.0	0.5		
IA12.	Assumes responsibility for the planning and execution of MR carried out under general	5.0	1.0		

	anaesthesia.				
IA13.	Assumes responsibility for the operation of MRI equipment at 1.5T and 3T.	6.0	1.0		
IA14.	Participates in oncology planning with MR-PET fusion imaging.	5.0	0.0		
IA15.	Assumes responsibility for the MR component of image acquisition in MR-PET.	5.0	1.0		
IA16.	*Discuss with radiologist* contraindications and psychological and / or somatic issues before patients attend the scan.	5.0	1.5	5.0	1.5
IA17.	Assumes responsibility for the evaluation of patient compatibility with MR procedure and imaging requirements.	6.0	1.0		
IA18.	Assumes responsibility for consulting with other MR stakeholders as necessary on issues related to the pathway including flagging of incidental findings to Radiologist and QA abnormal results to Medical Physicist.	6.0	1.0		
IA19.	Applies appropriateness criteria for MR referrals *following discussion with consultant radiologist*.	5.0	1.5	6.0	1.0
IA20.	*Applies prioritization guidelines following discussion with consultant radiologist*.	5.0	2.0	6.0	1.5
Education - The MR radiographer participates in the education of patients, public and health care professionals about procedures, devices, facilities, current services, safety and legislation. The radiographer contributes to quality healthcare professional education by participating in the education of medical imaging students and organization of medical imaging educational programmes.					
E1.	Assumes responsibility for providing information to patients before scanning and obtain informed consent.	6.0	1.0		
E2.	Participates in providing information on the diagnostic utility of different techniques and associated pulse sequences in the various areas of MR to healthcare professionals and specialty trainees.	5.0	1.0		
E3.	Participates in *multi professional* educational programmes aimed at ensuring that all MR stakeholders are informed about the various components of the MR Care Pathway (e.g., referral guidelines).	6.0	1.5	6.0	1.5
E4.	Participates in the provision of information about the strengths, limitations and safety of other stakeholders including the general public.	6.0	0.5		

E5.	Participates in the development of quality assured MR courses to MD and Non-MD Healthcare professionals.	6.0	0.0		
E6.	Assumes responsibility for mentoring student radiographers, and for participation in the education and training of student medical physicists and radiology trainees during their clinical placements	6.0	0.5		
Quality assurance ensures that high standards are maintained and includes quality control procedures carried out in a systematic and reliable manner. This means that all healthcare professionals and patients are satisfied with the quality and consistency of the MR examination. QA means consistent, effective, safe and efficient MR Care Pathway. For patients, QA nurtures confidence in consistently receiving a quality MR examination that meets the requirements of the procedure. The radiographer participates in QC programmes, documents and analyses the results and liaises with Medical Physicists when QC values are out of acceptance levels.					
QA1.	Participates in the establishment of objective quality criteria for the evaluation and monitoring of quality criteria at all stages of the care pathway.	6.0	1.0		
QA2.	Assumes responsibility for preparing and documenting a controlled radiographer's technical report for each scan. (Technical report would include information about patient assessment; image quality; SAR levels; clinical indications; sequence optimization, incidental findings or patient assessment).	6.0	0.5		
QA3.	Participates in the development, distribution, collection, analysis and reporting of patient satisfaction surveys.	6.0	0.0		
QA4.	*Participates in multi professional group* in auditing of the Care Pathway against national and local quality benchmarks (e.g., appropriateness of referrals, patient satisfaction, radiographer technical report).	6.0	0.5	6.0	1.0
QA5	*Participates in multi professional group* in the auditing of the effectiveness of the MR service against target patient management outcomes.	5.0	1.0	6.0	0.5
Safety and Risk Management relates to the overall safe care of the patient and/or their guardians, public and other workers. It involves the collection of data about the patient and procedure. The radiographer participates in the determination of the most appropriate action plan that results in enhanced safety to patient and others. The radiographer shares participation in the monitoring of MR and related devices, evaluation of clinical protocols to ensure the on-going protection of patients, and persons from the deleterious effects of physical agents and development of risk assessment tools (e.g safety screening forms, patient experience surveys).					
SRM1.	Assumes responsibility for risk assessment and the provision for the physical and psychological needs of patients before, during and after the scan.	6.0	0.5		
SRM2.	Assumes responsibility *for the application of standard safety operating procedures* in maintaining a working environment safe from hazards that could arise from chemical, physical and biological	6.0	0.5	6.0	1.0

	agents.				
Service Unit Management encompasses the performance or management of business operations and the making of any decisions to meet the goals of the organisation and the goals of the examination. It includes the day-to-day tasks of organising patient data and records, the management of staff, and resources.					
SUM1.	Participates in the delivery of information on and application of MR legislation.	6.0	1.0		
SUM2.	Participates in the update of local MR departmental regulations and procedures to any EU legislation and documentation.	6.0	1.0		
SUM3.	Participates in the use referral guidelines in order to prioritize accessibility to services.	6.0	1.0		
SUM4.	Participates in the development of Standard Operating Procedures (e.g., regulating non-MD referrals if these are implemented).	6.0	1.0		
Facility Management – Radiographers participate in the specification and selection of medical devices in accordance with the latest published European or International recommendations. The MR radiographer provides advice on the development of quality management systems. Provides advice on the human factors and ergonomics of MR equipment, accessories and room design. Advise policy makers on initiatives that address waiting list and productivity. Participates in health technology assessment activities.					
FM1.	Assumes responsibility for the provision of on call services on a 24/7 basis.	6.0	0.5		
FM2.	Assumes responsibility for the offer of advice on the management of resources including waiting list initiatives.	6.0	0.5		
FM3.	Participates *in a multi professional group* in the development of referral guidelines and the certification of MR referrers in order to grant referring privileges.	6.0	1.5	5.0	1.0
FM4.	Participates in activities for ensuring that quality and safety of MR services are ISO assured.	6.0	0.5		
FM5.	Participates in the procurement of MR scanners and associated medical devices.	6.0	1.0		
Research ensures that all activities will be based on current best evidence or own scientific research when the available evidence is not sufficient.					
RES1.	Takes responsibility for independent research or with other healthcare professionals.	6.0	0.5		

Table 6. 1 - Competence statements with corresponding median and IQR values. Modifications in competence statements for the second round of the Delphi are shown in italics.

6.6 Discussion

The aim of this objective was to develop and validate a competence profile that would list all the specific responsibilities required by radiographers to operate an MRI service in an effective, efficient and safe manner. The competence profile was developed from a forecasted 2020 service portfolio as well as an optimized MRI care pathway and from elements of good practice from the major English-speaking countries. The Delphi technique that has previously been used within education, particularly for curriculum development has also proved useful in this study. Many of the drawbacks of group meetings have been avoided, e.g. dominance by a few strong members, difficulties in reaching consensus and tendencies towards overload. There were no dropouts between round 1 and round 2. When the results of the first round were analysed 12 statements from the initial blueprint required modifications mainly highlighting that in interventional procedures (such as Deep Brain Stimulation planning and Breast Biopsy) the responsibility is within the remit of another healthcare professional (such as neurosurgeon or consultant radiologist) leading the intervention. In other statements such as those relating to auditing or benchmarking the modification referred to shared responsibilities with other healthcare professionals such as medical physicists rather than sole responsibility of the radiographer.

When the results of the second round were analysed the desired level of consensus was still not obtained on 3 statements (IA16, IA20, E3) which border on the traditional role of radiologists. Some of the comments from radiographers were:

'DBS planning under neurosurgeon's supervision is for junior radiographers.'

'Senior Radiographers can do this (MRI Cardiac) without supervision'

'Radiographers should take leading role' E3

'I have my reservations on the change, as same as for the other techniques mentioned, a well trained radiographer may be delegated the task of planning deep brain stimulation without the supervision of a neurosurgeon. Rather work together with the neurosurgeon' IA1

'We are undermining the potential of radiographers!' IA3

'a well trained radiographer should be able to assume this responsibility' IA3

This difference in opinion was expected in a modality which is still developing and where no clear lines of responsibility has been set between the professional groups which are all highly qualified both academically and in MRI practice. Meanwhile successful inter-professional relationships in healthcare are the basis for promoting collaborative healthcare (Little et al., 2014) and this can be achieved if the professions are motivated to practise together. Throughout the study, both the ABoE and the expert participants showed motivation towards collaboration and there was never any antagonism between the professions. However, this could be the result of the highly-structured Delphi and the Nominal Group Techniques which prohibit anyone from dominating others. The objective of this study was achieved because the final list of competences developed in this study is both contemporary as well as future oriented. This is not surprising because the competence profile was developed using a forecasted service portfolio, an optimized care pathway and elements of good practice in other countries. This is in contrast to studies by Edgren (2006), and Macdonald et al (2000) which ended up with a conventional list of competences because new technology and changes were not captured by the Delphi group. In these two studies participants focused on current practice because changes in the biomedical field had not yet come into routine use in hospital laboratories.

No other study on the development and validation of MRI competence profiles was found in the literature. However, comparing the results of this study with the components of a Master educational programme as approved by the EFRS in November 2016 and published in January 2017 is of interest ((European Federation of Radiographer Societies, 2017). It turns out that similarities between the elements in the master's programme (e.g., clinical audit, communication, devices and technology, research, management, risk management and quality control / assurance) and the key activities developed by the researcher and the competences validated in this objective in March 2016 are obvious. A common understanding of the MRI radiography profession at this higher level may have finally started to evolve in Europe.

The aim of the study was to find out which competences are needed by radiographers and to be able to use these competences to develop a detailed inventory of MRI physics learning outcomes. But the competence profile can also be used by employers to communicate their expectations to educators, guide professional development for employees and certify level of expertise which can be linked to career progression. The competence profile can be used by registration bodies to establish a specialist register.

Since in Malta a specialist register for Allied Health Care Professionals already exists, the competence profile could also be used to argue for inclusion of an MRI specialty for radiographers in this register.

6.7 Conclusion

In this objective, a competence profile for MR radiographers in Malta was established through the collaboration of a multi-stakeholder group of experts. The competence profile describes 43 competences grouped in 7 key activities that are required by radiographers to carry out the forecasted 2020 service portfolio and optimized care pathway. The competence profile will be the basis for the final phase of this project – the inventory of MRI biomedical physics learning outcomes, which will be reported in the next chapter.

Chapter 7: Objective 5 - to develop a comprehensive inventory of biomedical imaging physics knowledge and skills learning outcomes to support the competence profile developed in Objective 4.

7.1 Introduction

This chapter reports on the development and validation of an inventory of MRI biomedical physics learning outcomes (knowledge and skills) for MRI radiographers in Malta that would be required to deliver the competence profile developed in Objective 4 of this study.

7.2 Background

CPD with clearly planned out learning outcomes is of particular importance in MRI given its ever expanding role in the imaging of patients suffering from all types of pathologies and its increasing use in surgical interventions and cancer treatment. In developed countries including Malta, referrals for MRI cover from routine to complex scanning protocols as a result of technological improvements and also the increasing complexity of medical problems. As seen in the previous study radiographers in MRI have a responsibility to bridge the gap between the radiologist and the referrers, by providing first-hand information on the service portfolio and any incidental findings that would require immediate attention. Radiographers also participate in quality assurance teams, collaborating with medical physicists to optimize scanning protocols and ensure that the MRI equipment is safe for both patients and staff.

Although MRI biomedical physics learning outcomes are recognized as an important component of the body of knowledge that a radiographer in Malta is expected to have, the number of hours dedicated to MRI physics at undergraduate level is very limited. Thus, entry level radiographers would not have been systematically instructed on the physics required for effective, safe and efficient operating of MRI devices. Considering that certification frameworks are not in place, one can say that the link between CPD and service needs as advocated by experts in curriculum design (Harden, 1999; Huyghe et al., 2013; Lee et al., 2013) is absent. The introduction of new services together with technological upgrades in Malta requires radiographers to participate in CPD to update their knowledge and skills in all physics aspects of the MRI service. This situation was the major drive for the development of a comprehensive approach to develop and validate an inventory of MRI biomedical physics learning outcomes for radiographers, which would be used for the design of MRI physics curricula and CPD.

According to Lee et al (2013), curriculum development in healthcare should encompass everything from identifying the big picture (why is this curriculum necessary?) to the regular, planned evaluation of the effectiveness of the curriculum. The process of curriculum development should be conducted within 4 dimensions using Kern's six inter-related steps: problem identification and general needs assessment which includes addressing the needs of the patient population; needs assessment of targeted learners; formulation of goals and objectives; selection of instructional strategies; implementation; and evaluation and feedback. Regarding MRI, the problem and the needs were clear: Requests for MRI were increasing in complexity and volumes; society and health authorities have asked for better provision of care through the procurement of latest hardware and training. But due to lack of human resources and lack of CPD time available to radiographers, radiographer managers have asked for CPD to be tailored to the needs of local healthcare organizations. Once one clarifies the nature of the problem and assesses learning needs, the focus becomes the formulation of specific learning outcomes which would address those learning needs. Lee et al (2013) state that the success of CPD is dependent on an ongoing effort to ensure that the curriculum matches both patients' and learners' needs.

Defining curricular content helps to ensure that each step in the curriculum design process adequately represents the subject matter. This process, known as content definition or ''blueprinting'', refers to the systematic definition of content from a specified domain, for the purpose of creating learning outcomes with a high level of validity evidence (Tombleson et al., 2000; Shumway & Harden, 2003). Shumway and Harden (2003) highlight that two important features of contemporary medical education are recognized. The first is an emphasis on assessment as a tool to ensure quality in training programmes, to motivate students and to direct what they learn. The second is a move to outcome-based education where the learning outcomes are defined and decisions about the curriculum are based on these. These two trends are closely related. If teachers are to do a better job of assessing their students, they need deep knowledge of the learning outcomes to be assessed (Gambescia, 2006). For example, when designing the content for an obstetric curriculum, Cumyn and Harris (2012) systematically identified the content using published curricula and input from experts on the appropriateness of each previously identified learning outcome. *In this objective, the researcher will systematically focus on the content – an inventory of MRI physics learning outcomes which are to be considered a subset of a larger blueprint that would cover the entire learning outcomes inventory for MRI radiographers in Malta.*

Validity evidence is a concept that permeates every aspect of content definition. Regarding learning outcomes, validity evidence aims to provide support to the inference that the knowledge, skills and competences are what is required to work as an independent healthcare professional in the particular clinical context. Regarding this study, the first tasks were to outline in clear terms and using a formal research process the current and future service portfolio as well as the clinical care pathway.

This led to the realization of a competence profile which is necessary for the delivery of the service profile and clinical pathway. The physics inventory is a list of the physics knowledge and skills required to support the competence profile. In this way, every stage of the project was geared towards content identification, with validity evidence being sought and documented. After implementation of the curriculum, further validity evidence may be sought from other sources including student feedback and patient satisfaction. But that would be another study which is beyond the scope of this project.

7.3 Purpose

The researcher sought to develop a comprehensive inventory of biomedical imaging physics knowledge and skills learning outcomes to support the competence profile of MRI radiographers in Malta developed in objective 4 of this study.

7.4 Methodology

The following approach based on multistakeholder expert consensus was adopted to develop and validate the learning outcomes inventory.

Step 1: Developing and validating a competence profile for MRI radiographers in Malta by evaluation of the local context and forecasting future service profile and optimization of the patient pathway guided, when appropriate, by elements of good practice identified in a survey of competence profiles from the major English-speaking countries. This has been achieved in Objectives 1 – 4 of the study.

Step 2: Development of an initial version of the biomedical imaging physics learning outcomes inventory required to be able to deliver the competence profile via an analysis of textbooks and literature and the advice of the ABoE.

Step 3: Final validation of the biomedical imaging learning outcomes inventory via an international group of SMEs consisting of 5 radiographers, 5 radiologists and 5 medical physicists.

By reviewing the literature, the researcher first identified a comprehensive list of MRI textbooks and peer reviewed articles that described MRI biomedical physics. This rich resource (See list of textbook and articles in Appendix F) was used to develop an initial blueprint consisting of the physics knowledge and skills required for each competence in the competence profile. The content was then expressed in short phrases ensuring that the wording and level of detail reflected the purpose of the competence statement and intended to be meaningful even to an outside reviewer. It was immediately evident that there was content that was common to most of the competences. Therefore, a decision was taken to divide the structure of the inventory into two sections with FUNDAMENTAL Biomedical Physics knowledge and skills which are GENERIC TO ALL COMPETENCES and ADDITIONAL Biomedical Physics knowledge and skills SPECIFIC to each INDIVIDUAL competence. The fundamental knowledge and skills are expected to be acquired by all MR practitioners independently of their particular competence responsibilities. The additional knowledge (K) and skills (S) required of an individual radiographer would be those associated with the subset of competences in the competence profile which he/she practices.

An internal review of the initial inventory for content validity was performed by the ABoE. Once the initial inventory of biomedical MRI physics learning outcomes was approved by the ABoE it was subsequently validated by a bigger panel (n = 15) of external experts. The validity of the results depends on the credibility and expertise of those reviewing the inventory. Cumyn and Harris (2012) emphasise the qualifications of the SMEs with attention given to training, experience, and publications There is no firm consensus on the number of SMEs required. Although obtaining input, with full consensus from a very large number of SMEs and education experts may be ideal, in practice, this content validation approach depends largely on external constraints such as availability of expertise, cost, and time.

The ABoE was asked to assess each item in the initial inventory for appropriateness and accuracy of content, for redundancy with respect to other items, for being essential as opposed to simply desirable, and for clarity (Parsian & Am, 2009). A dichotomous scale (1=not essential, 2=essential) was used for content. The Content Validity Index (CVI) was used to estimate the validity of the items (Lynn, 1986). Owing to the large number of K and S learning outcomes only statements with a minimum CVI approval rating of 67% (i.e., at least 2 out of three experts in favour) were included in the final blueprint. The ABoE was also asked to suggest additions or deletions and provide an overall evaluation of the blueprint, with attention paid to comprehensiveness (whether the inventory adequately covers the domain content) and clarity hence ensuring face validity (Grant & Davis, 1997). The researcher proceeded in the creation of serial drafts based on the feedback of the ABoE. In total, there were 7 revisions which resulted in an inventory containing 324 knowledge and skill statements. The initial proposed inventory which include statement codes is given in Appendix G.

Final validation of the learning outcomes inventory by a large consensus group of SMEs was the third and final stage. Purposive sampling approach was used in the selection of participants, since it is desirable to source participants whose experience and knowledge relate to a specific topic. Morse (1994) and Hsu and Sanford (2007) indicate the following criteria for recruiting experts suitable to a study: the participant must have knowledge and experience of the phenomenon under scrutiny, they must have the capacity to express themselves, and must be willing to participate in the study. Purposive sampling is believed to enhance the trustworthiness of a study (Morrow, 2005).

Panel members were identified based on qualification and their clinical and research expertise in MRI. A minimum of 10 SMEs are recommended to yield acceptably consistent responses and to avoid chance agreement (Seo et al., 2015). In this study a panel of 15 international SMEs (5 radiographers, 5 radiologists and 5 medical physicists) participated in the final validation exercise. For recruitment, a "snowball" strategy was used based on the personal contacts of the advisory board members, who in turn proposed other suitable candidates in their professional settings. Once panel members were identified, a cover letter explaining the goals and processes of the project was sent via email. The cover letter included a link to the web based survey and consent to participate.

Owing to the large number of learning outcome statements (324) the survey did not consider various levels of agreement and consensus based on an extended Likert scale as in previous objectives but only to identify whether the listed knowledge and skills statements were required or otherwise (i.e., dichotomous scale with 2 levels of agreement only). The use of a dichotomous scale when the purpose of the consensus method is to seek convergence of opinions on the final product, is common (Edgren, 2006; Rocka & Morrish, 2010; Smesny & Bellah, 2012). As suggested by Beaudin (1999), no neutral ('neither agree nor disagree') point was used but each participant was given the option to comment if they thought that any particular learning outcome statement required a modification or if they thought that additional learning outcomes should be included. Only three additional learning outcomes were suggested and these were included or otherwise following discussions with the ABoE. The participant response data can be also found in Appendix G.

The level of consensus used by different researchers for inclusion of a particular learning outcome in the final version of an inventory is quite variable. Von der Gracht (2012) recommends to base the definition of a consensus level on accepted standard, such as political voting systems (e.g. simple majority, two-thirds majority). Stemler (2001) states that a typical guideline for evaluating the level of consensus is that of 70% or greater. Some researchers use a '75% or greater' participant consensus cut-off point (Edgren, 2006; Rocka & Morrish, 2010). Masud et al (2014) in developing a European curriculum for geriatric undergraduate medicine chose a 100% level of consensus. However, this is rare and only really appropriate for small inventories and when many consensus iterations are possible. For this study, the researcher chose 70% as the level of consensus for the final version of the inventory. This value was chosen to ensure that there is a right balance between avoiding an overlong inventory whilst avoiding losing knowledge and skills learning outcomes considered important by the ABoE. However, versions of the inventory at 80% and 90% levels of consensus were also considered. These would be utilised if CPD time is not sufficient to deliver the full 70% level of consensus inventory. Approval to carry out this objective was obtained from the University of Malta Research Ethics Committee (proposal no 004/2016).

7.5 Results

The final version of the inventory at the 70% level of consensus is shown in Table 7.1. The results of the participants survey are also shown in Appendix G. The knowledge and skill statements from the initial blueprint that were lost at the 70%, 80% and 90% levels of consensus are shown in Table 7.2. Table 7.3 shows an analysis of the knowledge and skills statements lost at the 70% version by profession including researcher's comments. High level of desirability within a given profession (5Y or 4Y) is highlighted as green, while low level of consensus (1Y or 2Y) is highlighted as red. Medium level of consensus (3Y) is highlighted as orange.

The level of desirability by profession data were analysed both qualitatively and quantitatively using the Fischer's exact test (SPSS) to evaluate whether there were any significant differences between the responses of the various professions (Cases et al., 2016; Taylor et al., 2016). Some qualitative difference was noted but at the level of statistical significance used (0.05 two-tailed) all quantitative results failed to reject the null hypothesis (all p values > 0.05). There was no significant difference between professions (See Appendix H). However, it should be emphasized that much bigger groups of participants and random sampling would really be required to make these statistical tests of hypothesis meaningful and of sufficient power. However, a large group of expert participants would in practice be difficult to get together for such studies. The data was therefore only discussed qualitatively. Quantitative data was analysed using the statistical package SPSS v.24 and Excel.

BIOMEDICAL IMAGING PHYSICS LEARNING OUTCOMES for MRI RADIOGRAPHERS	
FUNDAMENTAL biomedical Physics knowledge and skills GENERIC to ALL competences	
Knowledge statements	**Skill Statements**
Explain the basic laws of electromagnetism, relative magnitudes of electronic and nuclear magnetic dipoles, magnetic polarization, susceptibility and its different forms (electronic diamagnetism, paramagnetism, ferromagnetism; nuclear paramagnetism) and their relevance to MRI (classical description, basic quantum description). Distinguish between magnet types (permanent, resistive, superconducting, hybrid, niche) and advantages/disadvantages of each. Explain the basic physical properties of tissue for generating tissue contrast (SD, T1, T2, T2*, diffusion). Explain how an MRI signal is produced and weighted in SE, GRE sequences. Explain the appearance of a given MR image in terms of the relevant basic physical properties of normal/ pathological tissue, including the effect of contrast agents. Explain the use of preparation pulses (e.g., inversion recovery, fat saturation, steady state) and their use in modified sequences e.g., how inversion time is selected to suppress signal from a specific type of tissue.	Screen patients/visitors/personnel and ancillary devices for ferrous/ RF-sensitive material prior to entrance into magnetic field. Select (including the identification of specific transmit coils from receive-only coils and the safety implications), set-up and position appropriate RF coils for a given study. Select parallel imaging factor and direction relative to the coil elements. Manipulate pulse control and operator units, landmark, acquire scout image, prescribe slices and saturation bands, scan patient. Review relevant clinical information and records to determine examination technical requirements. Select appropriate examination protocol and acquisition parameters (e.g., TR, TE, FOV, slice thickness) to achieve target image quality criteria required by the clinical question and any patient requirements. Select protocol options (e.g., saturation pulse, fat suppression) to maximize diagnostic effectiveness.

Explain the need for the various types of RF coil (volume, surface local, surface arrays, internal), coil tuning, transmit and receive bandwidth. Explain use of gradient coils for slice selection and 2D/3D spatial encoding including gradient amplitude, rise time, slew rate, duty cycle, k-space as MR data space and k-space filling. Define and explain the relationship between the various image quality criteria (e.g., sharpness, conspicuity of detail) and basic device performance parameters (e.g., SNR, CNR, SR, field homogeneity) in MRI. Explain the various ways of reducing scan time e.g., fast sequences, partial k-space filling and associated trade-offs. Explain parallel imaging, effect of number of coil receive elements, and parallel imaging factor selection and direction relative to the coil elements. Explain the various types of MR image artefacts and ways of avoiding or compensating for these. Explain physical aspects of patient and occupational safety in MRI including bioeffects, tissue heating, SAR, fringe field and safety zones, noise protection, pregnancy and paediatrics, examinations requiring particular caution. Explain the principles of Magnetic Resonance Spectroscopy (MRS), why good signal-to-noise (SNR) in MRS is critical and how it may be optimised. Discuss the relative advantages and disadvantages of MRI at 1.5T and 3T. Understand the importance of consulting with other MRI stakeholders before applying changes in scanning protocols that would affect image quality or patient safety.	Adjust parameters or sequence to maintain SAR values within acceptable limits. Select alternative sequences to avoid/reduce artefacts (e.g., metal implant artifacts, susceptibility artifacts, flow compensation). Modify the examination according to the resultant findings and clinical presentation. Monitor image quality outcomes and distinguish between technically acceptable and unacceptable images. Perform appropriate image post-processing. Setup power injector including setting of appropriate dose according to patient weight. Consult with other MRI stakeholders before applying changes in scanning protocols that would affect image quality or patient safety.

ADDITIONAL biomedical Physics Knowledge and Skills SPECIFIC to each INDIVIDUAL competence		
Competence statements	**Knowledge statements**	**Skill statements**
Image Acquisition refers to the use of knowledge of anatomy, pathology and physics to produce images of high diagnostic effectiveness. The MR radiographer uses devices and optimizes imaging parameters to acquire the best possible images for interpretation.		
Assumes responsibility for the planning and execution of Neurology MRI including Diffusion Weighted Imaging, Magnetic Resonance Angiography, MRI tractography, MRI Neurography. Assumes responsibility for planning deep brain stimulation under neurosurgeon's supervision.	Explain the T2-FLAIR sequence and its use in brain imaging. Define diffusion and describe qualitatively the effect of tissue microstructure on rate of diffusion. Explain molecular diffusion rate (Mean Diffusivity (MD) or Apparent Diffusion Coefficient (ADC)). Explain how the MR signal is sensitised to diffusion, definition of b- value. Explain how the visualization of pathological processes is influenced by the choice of b-values. Explain common artefacts in DWI (e.g., T2 shine-through, eddy currents, bulk head motion, CSF pulsations, solid/soft tissue interfaces) and solutions e.g., use of Single Shot EPI. Distinguish between isotropic and anisotropic diffusion in the brain, the directional preference	Set up a head coil. Set up brain sequences including T2-FLAIR, DWI, DTI and higher resolution ROIs. Select/adjust b-values to maximize diagnostic effectiveness of DWI and DTI protocol Select/adjust number and direction of diffusion encoding gradients to maximize diagnostic effectiveness of DTI protocol. Use DWI and DTI software to provide scalar and tensor maps. Select/adjust TE values to maximize diagnostic effectiveness of MRN protocol. Select the appropriate MRA protocol to improve diagnosis. Set up flip angle, TR, TE values and MT in MRA sequences to enhance time of flight effects from

	of diffusion (Fractional Anisotropy (FA)), axial and radial diffusivities. Explain the principles of Diffusion Tensor Imaging (DTI) and white matter tractography Explain the principles of conventional brain MRA (time-of-flight, phase contrast, contrast enhanced, black and bright blood). Explain the principles of MR Neurography (MRN). Explain the principles of magnetization transfer imaging (MTI).	arteries. Select/adjust VENC values to maximize diagnostic effectiveness of phase contrast MRA. Select the appropriate bolus chasing technique to synchronize the acquisition of the central portion of k-space with the arrival of the contrast bolus. Perform multiplanar reconstructions in any arbitrary imaging plane as discussed with the reporting Radiologist.
Assumes responsibility for the planning and execution of Body MRI including Diffusion Weighted Imaging, Magnetic Resonance Angiography (MRA) and MR Enterography (MRE).	Explain the principles of half-Fourier acquisition with single shot fast SE acquisitions (T2W) and its use in clinical practice. Explain the principles of T1W dual echo (in phase, out of phase) Spoiled Gradient Echo (SGE) acquisitions; fat suppressed SGE and 3D Gradient Echo. Discuss the advantages and disadvantages of using respiratory gated / cardiac gated SS-EPI DWI in Body MRI. Explain the principles of fat-suppressed T1-weighted three-dimensional gradient recalled echo sequence	Set up abdomen RF coil according to vendor and Medical Physicist specifications. Set up respiratory and cardiac triggering. Select body protocols for both cooperative and uncooperative patients Select scan protocols (TR / TE values) to maximize diagnostic effectiveness within breath hold capabilities of the patient Select the appropriate receive bandwidth in conjunction with fat suppression techniques to improve SNR and reduce chemical shift artefact Select/adjust b-values to maximize diagnostic effectiveness of DWI protocol according to the

	Explain the principles of motion resistant protocols (MP-RAGE sequence; 3D Radial GRE sequence; single shot echo train SE). Explain how the artefacts associated with abdominal imaging (respiratory motion, intrinsic motion, chemical shift, susceptibility artefacts) can be reduced by utilizing faster gradients, breath-hold sequences and fat suppression techniques. Explain the relevance of low and high 'b' values in the investigation of diseases of the liver, pancreas, urinary tract and bowel. Explain the principles of MRE including fat suppression and DWI. Explain the principles of non-contrast enhanced MRA techniques based on steady-state sequences. Explain the principles and use of negative enteric contrast, positive enteric contrast and biphasic contrast medium for MRI of the bowel in MR Enterography.	organ being investigated. Generate and analyse ADC maps. Select/ adjust TI values to maximize the diagnostic effectiveness of non-contrast MRA. Select the appropriate contrast medium for imaging the various organs/tissues in body imaging. Perform subtraction of pre-contrast and post-contrast images to identify enhancing lesions.

Assumes responsibility for the planning and execution of Breast MRI. MRI guided biopsy of the breast is planned under supervision of breast specialist.	Explain physics aspects for breast MRI including magnetic field homogeneity across both breasts, adequate magnetic field gradients to permit fast GRE imaging and use of bilateral breast coil for prone positioning. Explain the different fat suppression techniques commonly used in breast imaging (STIR, frequency selective pulses, combined frequency selective and STIR, Dixon method). Explain subtraction techniques used during breast imaging. Explain the technical considerations and imaging parameters for multiphase 3D GRE T1-weighted series acquired before and at repeated intervals after MR contrast-agent. Explain the principles of high in-plane resolution (pixel sizes less than 1mm), high temporal resolution (1-3min) with adequate SNR in order to differentiate between benign and malignant lesions. Describe the physical properties of silicone relevant to MR. Explain water-suppressing and fat-nulling sequences for evaluation of breast implants and soft tissue extra-capsular silicone.	Set up the breast coil. Adjust the FOV and matrix to maximize in-plane resolution. Perform shimming for local magnetic field inhomogeneity. Select centre frequency for water, fat and silicone from spectral peaks. Select the appropriate contrast medium for breast imaging. Select imaging parameters that place the maximum contrast-weighting of the first post-contrast series at or near the time of peak contrast agent uptake. Perform subtraction of pre-contrast and post-contrast images to identify enhancing lesions in breast MRI. Produce and analyse Maximum Intensity Projection (MIP) images of subtracted images for vascular bed assessment.

	Explain the principles underlying silicone-suppressing sequences Explain the relevance of optimized scan parameters in Fast SE sequences used specifically for breast implant imaging. Explain the importance of local shimming. Explain respiratory, cardiac motion, non-uniform fat suppression, wrap around artefacts in breast imaging and how these could be minimised. Explain qualitatively why central lines of k-space are acquired at the time of highest concentration of contrast agent. Explain the meaning of Maximum Intensity Projection (MIP) images.	

Assumes responsibility for the planning and execution of Musculoskeletal (MSK) MRI including MRI arthrography and Kinematic MRI (e.g., patellar tracking).	Explain the technical considerations (T1 relaxation times, chemical shift, SNR, fat saturation, RF deposition, RF coils) when using higher field strengths (1.5T vs 3.0T) for MSK. Explain use of phase array coils and parallel imaging in MSK. Explain the advantages and disadvantages of using intermediate TE when compared to long TE SE sequences in MSK. Explain the use of ultrashort TEs in the assessment of cortical bone, tendons and ligaments. Discuss technical considerations for direct and indirect MR arthrography (T1 Fat saturation, artefact associated with intra-articular gadolinium). Explain current MR imaging techniques to assess morphologic status of cartilage including conventional SE and GRE, fast SE, isotropic 3D SE and GRE.	Select and connect dedicated phase-array coils appropriate to the MSK area under investigation. Produce image contrast values to maximize the diagnostic effectiveness at 1.5T or 3.0T. Select/ adjust the TE values for proton density imaging including those acquired with fat suppression. Select/modify the scanning protocol in the presence of metallic orthopaedic implants. Select the best imaging plane to maximize diagnostic effectiveness Set up the scanner for kinematic assessment of joints.

Assumes responsibility for the planning and execution of MR Cholangiopancreatography (MRCP), MRI Liver, MRI Pancreas and MRI Liver Elastography	Explain the scan parameters of 2D and 3D single shot Fast SE sequence in generating MRCP images. Explain the underlying physics in using dual GRE sequences. Explain how respiratory and pulsation artefacts can mimic pathology.	Choose appropriate scan parameters for 2D and 3D single shot Fast SE sequence for generating MRCP images. Select/adjust TE values to maximize liver tissue contrast. Apply respiratory gating or respiratory compensation to reduce motion artefacts. Apply pre-saturation pulses to decrease flow motion artefact. Select/adjust receive bandwidth and fat saturation techniques to reduce chemical shift artefact. Select parallel imaging technique to maximize spatial resolution. Perform subtraction of pre-contrast and post-contrast images to identify enhancing lesions.

Assumes responsibility for the planning and execution of MRI male pelvis including prostate and rectum	Explain the technical considerations (choice of coils, motion artefacts) when imaging the male pelvis. Explain the technical considerations for high resolution multiparametric sequences (T2W, DWI and DCE-MRI) when imaging the prostate and rectum. Explain the relevance of T2-weighted Half-Fourier single-shot fast spin-echo (SSFSE) in imaging the rectum.	Set up an endorectal coil in conjunction with a phased array coil for imaging of the prostate; for other areas phased array coil. Select/modify the scanning parameters to achieve high resolution T2W sequences in 3 orthogonal planes for prostate and rectum. Select asymmetric FOV to acquire fine matrix in conjunction with shorter scan time. Select a range of b-values to maximize the diagnostic effectiveness of the DWI protocol in prostate and rectum imaging.

Assumes responsibility for the planning and execution of MRI female pelvis including uterus, cervix, and ovaries.	Explain technical consideration (high resolution T2W / T1W FSE sequences; Dynamic T1W CM sequences) for female pelvis. Explain fast real-time imaging (single shots FSE; balanced SSFP) for dynamic imaging in assessment of pelvic floor dysfunction. Discuss the use of endovaginal coils in obtaining high resolution images of urethra.	Place endovaginal coil to maximize image quality of the urethra. Setup phased array in the imaging of the female pelvic organs. Set up the patient and contrast media used during assessment of pelvic floor in order to reduce motion artefacts. Select/adjust flip angle, TR and TE values to maximize the image quality in T1W GRE sequence. Select/modify the scanning parameters to achieve high resolution T2W sequences in 3 orthogonal planes for female pelvis. Select/adjust the imaging planes for imaging of the uterus including dynamic contrast enhanced imaging of uterus for staging endometrial carcinoma.

Assumes responsibility for the planning and execution of Paediatric MRI.	Explain the protocol parameters that are modified to optimize SNR (coil selection, voxel size, acquisition time,) for children. Explain the scan parameters adjustments to optimize contrast for different spectrum of disease compared to adults. Explain fast imaging scans to reduce acquisition time in paediatric imaging. Explain how respiratory motion artefacts could be reduced in paediatric imaging. Explain the use of fluid sensitive sequences (T2W Fat sat; STIR, PD and 2DFFE) in paediatric protocols (Bare Bone protocol). Discuss how DWI acquisition needs to be modified in paediatric imaging.	Select the ideal RF coil for paediatric imaging paying attention to SAR safety. Select/adjust TR, TE values and voxel size to maximize image quality criteria in paediatric imaging. Adjust the TI (inversion time) value in STIR to improve the Signal to Noise resolution. Select a motion reducing strategy to improve image quality. Select receive bandwidth, number of excitations and phase encoding steps to maximize the acquisition time. Select a range of b-values to maximize the diagnostic effectiveness of paediatric imaging.

Shares responsibility for the planning and execution of MRI sequences requested for the assessment of change in tumour burden as a measure of treatment response or tumour progression.	Discuss the clinical application of MR permeability imaging to tumour investigation and other disorders.	Carry out system calibration prior to MR Spectroscopy (MRS) as applied to tumour progression and treatment follow-up. Choose appropriate voxel position. In CSI select the appropriate TE to maximize the characterization different regions of normal tissue and tumour. Calculate metabolite ratios using the available software. Carry out post-processing of spin labelling images (control and tag images) as per current recommended guidelines.

Shares responsibility for the planning and execution of MRI cardiac procedures under supervision of a cardiac specialist.	Explain the MRI system components for high quality cardiac MRI (cardiac coil, ECG vector gating, high speed gradient coils). Explain respiratory compensation methods and cardiac synchronised fast and ultra-fast (single-shot) sequences. Explain FSE, double/triple inversion recovery for morphological ('black-blood') imaging. Explain spoiled gradient echo and balanced steady state free precession (BSSFP) for functional dynamic ('bright-blood') imaging. Explain dynamic myocardial tagging with spatial modulation of magnetisation (SPAMM). Explain the use exogenous contrast agents to modify contrast (myocardial perfusion imaging using single shot technique with a fast (or turbo) spoiled gradient echo (FGE), balanced steady state free precession (BSSFP), or echo planar imaging (EPI). Explain the principles of viability imaging (late gadolinium enhancement).	Set up cardiac coil. Set up ECG triggering paying particular attention to ECG cable placement safety issues. Select and plan the Magnetization-prepared fast GRE sequences for maximized diagnostic effectiveness of myocardial perfusion. Select and adjust the TR and flip angle in GRE sequences to maximize contrast between myocardium and blood pool. Perform shimming to acquire a full three-dimensional cine BSSFP dataset in a single breath hold. Select the optimal TI time to achieve complete signal nulling from normal myocardium during late gadolinium enhancement. Select a pulse sequence scheme that allows for accurate in vivo T1 measurements and T1 mapping of myocardium with high spatial resolution and within a single breath-hold.

Assumes responsibility for the planning and execution of vascular MRI.	Explain the physics of flow, flow phenomena, and flow phenomena compensation. Explain conventional MRI vascular imaging techniques (Time of Flight, phase contrast MRA, Contrast enhanced MRA, black blood imaging, bright blood imaging).	Select the appropriate MRA technique to maximize the diagnostic effectiveness. Select/adjust Flip angles and TE values to maximize image quality of MRA. Select / adjust VENC values to maximize diagnostic effectiveness of phase contrast MRA. Place saturation bands to reduce signal from either arterial or venous flow. Select the appropriate ramping technique in 3D TOF MRA to improve signal intensity.
Assumes responsibility for the planning and execution of MRI carried out under general anaesthesia.	Explain the principles of the physiological monitoring instruments used by the anaesthetist.	Evaluate the need for the use of specific ancillary equipment. Set up and use physiologic monitoring equipment as directed by anaesthetist.

Assumes responsibility for the operation of MRI equipment at 3T.	Explain the advantages and disadvantages of 3T MRI in terms of image quality criteria, device performance indicators, safety. Explain the effects of higher magnetic field in relaxation effects, spin labelling, chemical shift at 3T. Discuss compensatory measures to the effects of 3T on SNR, CNR and SAR levels. Explain the principles of advanced neuro-imaging applications at 3T including MR Spectroscopy; fMRI; DWI, susceptibility weighted imaging; perfusion imaging; diffusion tensor imaging. Explain the principles of advanced abdominal imaging applications at 3T including chemical shift imaging. Explain the principles of advanced cardiovascular imaging applications at 3T. Explain the challenges in image quality criteria when considering breast and musculoskeletal MRI at 3T.	Select / adjust TR values in T1W sequences to improve SNR at 3T. Select /adjust receive bandwidth to reduce the effects of chemical shift at 3T. Keep a vigilant look on SAR values when adjusting scanning parameters (TR, Flip angle) at 3T. Select / adjust TR/TE values to reduce acquisition time at 3T. Select / adjust voxel dimension to increase spatial resolution without affecting acquisition time at 3T. Select / adjust TE values to maximize chemical shift imaging in the abdomen at 3T. In T2W sequences select techniques (RF cushioning, multichannel coils) to mitigate against RF shielding, standing wave artefacts and B1 inhomogeneity. Select/adjust TI to allow adequate relaxation of longitudinal magnetization in cardiac LGE imaging at 3T.

Participates in oncology planning with MRI-PET fusion imaging.	Explain the principles and aims of multimodality imaging; image co-registration; and longitudinal imaging. Explain the principles of MRI techniques used for treatment planning and simulation in oncology. Explain the impact of artifacts (e.g., tissue misclassification) and geometric distortions in oncology planning.	To set up the laser beams alignments necessary for PET-MRI fusion. Use PET-MRI imaging software for oncology planning in partnership with the nuclear medicine radiographer
Assumes responsibility for the MRI component of image acquisition in MRI-PET.	Explain the principles and aims of multimodality imaging, image co-registration and longitudinal imaging. Explain the relevance of in-plane resolution when optimizing MRI protocols for MRI-PET.	Acquire MRI-PET images in partnership with the nuclear medicine radiographer. Use MRI-PET software for MRI-PET in partnership with the nuclear medicine radiographer.
Assumes responsibility for the evaluation of patient compatibility with MRI procedure and imaging requirements	Same knowledge as for Safety and Risk Management (SRM) competences SRM1 and SRM2 below. Explain patient compatibility issues within the context of MRI.	Same skills as for Safety and Risk Management (SRM) competences SRM1 and SRM2 below. Take actions to modify the MRI procedure to ensure patient compatibility.

Assumes responsibility for consulting with other MRI stakeholders as necessary on issues related to the MRI pathway including flagging of incidental findings to Radiologist and QA abnormal results to Medical Physicist.	Define relevant MRI device performance (including safety related) indicators used in pre-scan QC constancy testing as agreed with the Medical Physicist; state warning and acceptability limits. Define relevant post-scan physics image quality and safety criteria as agreed with the Medical Physicist; describe their method of measurement and state warning and acceptability limits. Understand any specific QA requirements of specific protocols and/or patient population. Discuss the procedure for escalating quality issues to the Medical Physicist and manufacturer/service provider, and how this is followed up.	Evaluate results of device pre-scan QC (including safety related) constancy testing as agreed with the Medical Physicist; flag values beyond warning and acceptability limits. Evaluate results of post-scan QC physics image quality and safety criteria assessment as agreed with the Medical Physicist; flag values beyond warning and acceptability limits. Correct common faults through appropriate procedure, report other faults to Medical Physicist.
Applies appropriateness criteria for MRI referrals following discussion with consultant Radiologist.	No additional Physics knowledge or skills.	
Education - The MR radiographer participates in the education of patients, public and health care professionals about procedures, devices, facilities, current services, safety and legislation. The radiographer contributes to quality healthcare professional education by participating in the education of medical imaging students and organization of medical imaging educational programmes.		
Assumes responsibility for providing information to patients before scanning and obtain informed consent.	Explain the regular physics-related information that should be provided to patients (particularly sequence instructions and patient safety related) and rationale for providing said information.	Communicate regular physics-related information to patients and evaluate the effectiveness of such communication.
Participates in providing information on the diagnostic utility of different MRI techniques and	Explain regular physics-related information that should be provided to the various healthcare	Communicate regular physics-related information to healthcare professionals and specialty trainees

associated pulse sequences in the various areas of MRI to healthcare professionals and specialty trainees.	professionals and specialty trainees (particularly strengths and limitations of the various studies, sequence instructions, patient and occupational safety related) and rationale for providing said information.	and evaluate the effectiveness of the communication.
Participates in the provision of information about the strengths, limitations and safety of MRI to other stakeholders including the general public	Explain regular physics-related information that should be provided to other stakeholders including the general public (particularly strengths and limitations of the various studies, patient and occupational safety related) and rationale for providing said information.	Communicate to other stakeholders including the general public regular physics-related information (particularly strengths and limitations of the various studies, patient and occupational safety related) that should be provided to them and evaluate the effectiveness of the communication.
Participates in the development of quality assured MRI courses to MD and Non-MD healthcare professionals.	Demonstrate sufficient understanding of regular physics related terminology to be able to liaise with Medical Physicists in the development of quality assured MRI courses to MD and Non-MD healthcare professionals.	Use regular physics terminology sufficiently well to be able to liaise with Medical Physicists in the development of quality assured MRI courses to MD and Non-MD healthcare professionals.
Assumes responsibility for mentoring student radiographers, and for participation in the education and training of student Medical Physicists and trainee Radiologists during their clinical placements	Demonstrate sufficient understanding of regular physics related terminology to liaise with trainee Medical Physicists and trainee Radiologists during their clinical placements.	Use regular physics terminology sufficiently well so as to be able to liaise with trainee Medical Physicists and trainee Radiologists during their clinical placements.

Quality assurance ensures that high standards are maintained and includes quality control procedures carried out in a systematic and reliable manner. This means that all healthcare professionals and patients are satisfied with the quality and consistency of the MR examination. QA means consistent, effective, safe and efficient MR Care Pathway. For patients, QA nurtures confidence in consistently receiving a quality MR examination that meets the requirements of the procedure. The radiographer participates in QC programmes, documents and analyses the results and liaises with Medical Physicists when QC values are out of acceptance levels.		
Participates in the establishment of objective quality criteria for the evaluation and monitoring of service quality at all stages of the care pathway.	Demonstrate sufficient understanding of physics-related terminology to be able to liaise with Medical Physicists in the establishment of acceptable values for pre-scan device performance indicators and post-scan image quality and safety criteria.	Liaise effectively with Medical Physicists in the establishment of acceptable values for pre-scan device performance indicators and post-scan image quality and safety criteria.

Assumes responsibility for preparing and documenting a controlled radiographer's technical report for each scan. (Technical report would include information about patient assessment; image quality; SAR levels; clinical indications; sequence optimization, incidental findings or patient assessment).	Explain the importance of pre-scan device QC constancy testing for a quality service. Explain the bioeffects of static and dynamic electromagnetic fields on patients. Explain the meaning of SAR and its relevance to MRI safety. Explain the need for measuring patient mass prior to scanning and its input into the scanner. Define relevant device MRI device performance (including safety related) indicators used in pre-scan QC constancy testing as agreed with the Medical Physicist; describe their method of measurement and state warning and acceptability limits. Explain the physics underlying the QC test objects used in constancy testing. Explain the importance of post-scan assessment of physics image quality and safety criteria for the MRI pathway. Define relevant post-scan physics image quality and safety criteria as agreed with the Medical Physicist; describe their method of measurement and state warning and acceptability limits.	Carry out ongoing device pre-scan QC constancy (including safety related) testing as agreed with the Medical Physicist; evaluate results and flag values beyond warning and acceptability limits. Check that patient pre-scan safety screening form is properly filled in and signed. Record patient mass and SAR level, confirm within acceptable level. Carry out ongoing device post-scan assessment of physics image quality and safety criteria as agreed with the Medical Physicist; evaluate results and flag values beyond warning and acceptability limits. Correct common faults through appropriate procedure, report other faults to Medical Physicist. Ensure all physics parameters are recorded in an appropriate manner in the technical report. Assess the quality of own technical report.

Participates in the development, distribution, collection, analysis and reporting of patient satisfaction surveys.	No additional Physics knowledge or skills.	
Participates in multi professional group in auditing of the MRI Care Pathway against national and local quality benchmarks (e.g., appropriateness of referrals, patient satisfaction, radiographer technical report)	Demonstrate sufficient understanding of physics-related terminology to be able to liaise with Medical Physicists in the in the auditing of the MRI Care Pathway against national and local quality benchmarks.	Liaise with Medical Physicists in the in the auditing of the MRI Care Pathway against national and local quality benchmarks. Cooperate with Medical Physicists in internal audits with respect to physics-related national and local quality benchmarks. Cooperate with Medical Physicists in with respect to physics-related national and local quality benchmarks.
Participates in multi professional group in the auditing of the effectiveness of the MRI service against target patient management outcomes.	Demonstrate sufficient understanding of physics-related terminology to be able to liaise with Medical Physicists in the in auditing of the effectiveness of the service against target patient management outcomes.	Cooperate with Medical Physicists in auditing of physics-related service effectiveness aspects against target patient management outcomes.
Safety and Risk Management relates to the overall safe care of the patient and/or their guardians, public and other workers. It involves the collection of data about the patient and procedure. The radiographer participates in the determination of the most appropriate action plan that results in enhanced safety to patient and others. The radiographer shares participation in the monitoring of MR and related devices, evaluation of clinical protocols to ensure the on-going protection of patients, and persons from the deleterious effects of physical agents and development of risk assessment tools (e.g safety screening forms, patient experience surveys).		
Assumes responsibility for risk assessment and the provision for the physical and psychological needs of patients before, during and after the scan	Explain the risks within the MRI environment to patients, staff and visitors. Explain the meaning of SAR and its relevance to	Carry out risk assessment and take measures to eliminate / reduce risks. Liaise with Medical Physicists to ensure that any

	patient risk. Discuss the effects of static and gradient magnetic fields on the human body including the unborn child. Explain what happens when RF (radio frequency) is pulsed into the body. Explain and compare safety concerns associated with both external and internal (to the magnet) areas of the magnetic field. Distinguish between MR safe, unsafe and conditional items and devices. List and briefly explain the types of medically implanted metal objects that might be found in a patient's body and can be a potential hazard when the patient is placed in a magnetic field. Explain the procedure for determining if a specific medical device, such as a surgical clip, is a potential hazard when the patient is placed in a magnetic field. Identify the conditions that can produce skin burns during an MRI acquisition and explain the steps to take to prevent them. Explain the hazards associated with acoustic noise.	items/devices brought into the MR room are checked for MR safe/unsafe/conditional status and their use or otherwise stipulated within the local Code of Practice. Carry out pre-scan patient safety screening, ensure screening form is properly filled in and signed, patient mass measured and inputted to system. Collaborate with Medical Physicists in the setting up of a local Code of Practice. Adhere to national, European and international legislation/recommendations regarding the safe use of MRI for patients, staff and visitors with respect to all physical agents within the MR environment.

Assumes responsibility for the application of standard safety operating procedures (SOP) in maintaining a working environment safe from hazards that could arise from chemical, physical and biological agents.	Explain physics related issues within local SOPs (including any associated Codes of Practice). Explain the relevance of the screening procedure required for an individual and patient prior to being allowed into to the MRI environment or to undergo an MRI examination. Explain national, European & international legislation/recommendations regarding safe use of MRI for patients, staff, visitors. Explain when and how to quench the magnet and handle other emergencies in the MR environment. Explain completely the procedures to be followed to prevent hazardous metal objects to be brought into the magnetic field area.	Adhere to physics related issues within local SOPs (including any associated Codes of Practice).
Service Unit Management encompasses the performance or management of business operations and the making of any decisions to meet the goals of the organisation and the goals of the examination. It includes the day-to-day tasks of organising patient data and records, the management of staff, and resources.		
Participates in the delivery of information on and application of MRI legislation.	Same additional physics knowledge and skills as for competences SRM1 and SRM2.	
Participates in the update of local MRI departmental regulations and procedures to any EU legislation and documentation.	Same additional physics knowledge and skills as for competences SRM1 and SRM2.	
Participates in the use of referral guidelines in order to prioritize accessibility to services.	Explain physics related issues included in European/National/local referral guidelines.	Liaise with Medical Physicists in the application of physics-related issues included in European/National/local referral guidelines.

Participates in the development of Standard Operating Procedures (e.g., regulating non-MD referrals if these are implemented).	Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in the in the development of Standard Operating Procedures.	Liaise with Medical Physicists in the development of Standard Operating Procedures.
Facility Management – Radiographers participates in the specification and selection of medical devices in accordance with the latest published European or International recommendations. The MR radiographer provides advice on the development of quality management systems. Provides advice on the human factors and ergonomics of MR equipment, accessories and room design. Advise policy makers on initiatives that address waiting list and productivity. Participates in health technology assessment activities.		
Assumes responsibility for the provision of on call services on a 24/7 basis.	No additional Physics knowledge or skills.	
Assumes responsibility for the offer of advice on the management of resources including waiting list initiatives.	No additional Physics knowledge or skills.	
Participates in activities for ensuring that quality and safety of MRI services are ISO assured.	Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in ISO certification applications.	Liaise with Medical Physicists in ISO certification applications.
Participates in the procurement of MRI scanners and associated medical devices.		Liaise with Medical Physicists in the procurement of MRI scanners and associated medical devices.

Research ensures that all activities will be based on current best evidence or own scientific research when the available evidence is not sufficient.		
Takes responsibility for independent research or with other healthcare professionals	Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in MRI research. Explain the three IEC operating modes (normal, first-level and second-level controlled) and relevance to MRI research. Understand the importance of adhering to agreed scanning protocols in clinical research trials.	Liaise with Medical Physicists in MRI research.

Table 7. 1 - Final version of the inventory at the 70% level of consensus

Inventory section	K&S rejected at 70% consensus level		Additional K&S rejected at the 80% consensus level		Additional K&S rejected at the 90% consensus level	
	Knowledge	Skills	Knowledge	Skills	Knowledge	Skills
Fundamental	FUNK14				FUNK1, FUNK2, FUNK13,	FUNS3, FUNS7, FUNS10,
Image Acquisition (IA)	IA1K8, IA1K9, IA2K2, IA2K9, IA3K11, IA4K5, IA4K6, IA4K8, IA4K10, IA5K2, IA5K4, IA5K6, IA5K7, IA5K8, IA5K9 IA5K10, IA6K3, IA6K4, IA7K2, IA8K6, IA9K1, IA9K2, IA9K4, IA9K5 IA9K6, IA10K5, IA10K8, IA10K9, IA11K3, IA14K4, IA15K2, IA15K4,	IA3S8, IA4S4, IA6S5, IA6S6, IA9S1, IA9S6, IA11S6,	IA1K6, IA2K8, IA4K3, IA4K4, IA4K9, IA6K5, IA7K3, IA10K6, IA10K7, IA13K4, IA13K6	IA1S4, IA1S5, IA2S6, IA2S7, IA4S2, IA2S7, IA6S1, IA6S4, IA8S6, IA9S2, IA9S5, IA9S7,	IA1K4, IA1K7, IA1K11, IA1K12, IA2K1, IA2K5, IA2K8, IA2K11, IA2K12, IA3K4, IA3K5, IA3K7, IA3K8, IA3K9, IA3K13, IA4K1, IA4K7, IA5K3, IA8K2, IA8K5, IA9K3, IA10K3, IA10K4, IA10K10, IA12K1, IA13K5, IA14K1, IA14K3, IA15K1, IA15K3, IA18K1, IA18K2, IA18K3	IA1S3, IA1S6, IA1S8, IA1S9, IA2S5, IA2S9, IA2S10, IA3S3, IA3S5, IA3S6, IA3S9, IA4S3, IA5S1, IA5S2, IA5S6, IA6S2, IA7S1, IA7S4, IA7S6, IA8S5, IA9S3, IA9S4, IA10S3, IA10S4, IA10S5, IA10S6, IA10S7, IA11S2, IA11S5, IA12S1, IA13S4, IA13S6, IA13S7, IA13S8, IA14S2, IA15S2, IA18S2
Education (E)					E4K1	E4S1
Quality Assurance (QA)			QA2K6, QA5K1	QA2S4, QA5S1	QA1K1, QA2K1, QA2K2, QA2K5, QA2K7, QA2K8,	QA1S1, QA2S1, QA2S3, QA2S7, QA4S1, QA4S2, QA4S3,
Safety and risk						SRM1S4

management (SRM)						
Service Unit Management (SUM)					SUM1, SUM3K1, SUM4K1,	SUM1, SUM3S1
Facility Management (FM)	FM3K1, FM5K1	FM3S1		FM5S1	FM4K1	FM4S1
Research (R)			R1K1			R1S1

Table 7. 2 - Knowledge and Skills statements from the original proposed inventory rejected at the 70%, 80% and 90% levels of consensus (Please refer to Appendix G for the full knowledge and skills statements).

Knowledge or skill lost at 70%	Radiographer		Radiologist		Medical Physicist		Researcher's comments
	Y	N	Y	N	Y	N	
FUNK14. Explain the principles of Chemical Shift Imaging (CSI	4	1	4	1	2	3	FUNK14 was the only statement rejected from the Fundamental Knowledge section.
IA1K8. Explain the need for high b-values, need for a minimum of 6 non-collinear diffusion encoding directions, basic calculation of optimal b-value.	5	0	3	2	2	3	In the IA1 competence (*Assumes responsibility for the planning and execution of Neurology MRI including Diffusion Weighted Imaging, Magnetic Resonance Angiography, MRI tractography, MRI Neurography*) IA1K9 was rejected by all professions (RG and RD 60%, MP80% rejection). This is probably due to the application being too advanced and reserved for specialized sites doing functional imaging.
IA1K9. Provide a basic interpretation of ellipsoid glyphs, diffusion tensor, eigenvalues, eigenvectors	2	3	2	3	1	4	
IA2K2. Explain the principles of balanced steady state free precession (BSSFP) and its use in rapid morphological imaging.	3	2	4	1	3	2	IA2K9 was rejected by majority of radiographers possibly pointing to the fact that such knowledge is only needed for diagnosis rather than understanding the use of DWI in differentiating low cellular tumours from high cellular tumours.
IA2K9. Explain the relevance of DWI and associated ADC maps to investigate high and low cellularity of tumours.	2	3	5	0	3	2	

IA3K11. Explain the use of time-enhancement (time-intensity) curves	2	3	4	1	4	1	Knowledge and skills statements on time intensity curves for breast imaging (IA3K11) was rejected by majority of radiographers (60%) again pointing to the possibility that this knowledge and skills is only needed by radiologists.
IA3S8. Analyze time-enhancement (time-intensity) curves	2	3	4	1	3	2	
IA4K5. Explain the physics underlying the magic-angle effect associated with intermediate TE spin echo sequences	3	2	4	1	2	3	5 statements were rejected from competence IA4 (*Assumes responsibility for the planning and execution of Musculoskeletal (MSK) MRI including MRI arthrography and Kinematic MRI (e.g., patellar tracking*). While K8, K10 and S4 all relate to non-routine application, it is quite surprising to note that radiographers did not vote all in favour on K5 (magic angle) and K6 (Inhomogeneity) which relate frequent dilemmas in MSK imaging.
IA4K6. Explain methods that allow images to be obtained in the presence of the inhomogeniety caused by orthopaedic implants (Dixon-based methods, prepolarized MR imaging, view angle tilting).	3	2	4	1	2	3	
IA4K8. Discuss technical considerations for kinematic MRI in MSK (dynamic phase contrast sequences, single slice, spiral real-time sequences, open MR systems vs short bore MR systems).	2	3	4	1	2	3	
IA4K10. Explain compositional assessment techniques include T2 mapping, delayed gadolinium-enhanced MR imaging of cartilage (dGEMRIC), T1ρ imaging, sodium imaging, DWI and MR spectroscopy.	2	3	3	2	2	3	
IA4S4. Select / adjust for uTE to maximize image quality in the assessment of cortical bone, tendons	3	2	5	0	2	3	

	and ligaments.							
	IA5K2. Discuss the use of negative contrast with high manganese content in MRCP imaging	2	3	4	1	2	3	7 statements from competence IA5 (*Assumes responsibility for the planning and execution of MR Cholangiopancreatography (MRCP), MRI Liver, MRI Pancreas and MRI Liver Elastography)* were rejected. The statements were related to pharmacokinetics, iron overload imaging and elastography. The main comment was that '*Many of the topics here are very advanced and/or specialised I don't think necessary for the radiographer*.'
	IA5K4. Explain the pharmacokinetics	3	2	3	2	2	3	
	IA5K6. Explain when to use hepatocyte specific contrast medium and when to use extracellular contrast agents including bolus timing to achieve peak arterial enhancement	3	2	3	2	3	2	
	IA5K7. Explain qualitative and quantitative techniques (signal intensity ratio, relaxometry) used to measure presence of iron in liver	2	3	3	2	3	2	
	IA5K8. Explain the different qualitative and quantitative methods to assess fat deposition in the liver, e.g. chemical shift imaging and MR spectroscopy.	3	2	4	1	2	3	
	IA5K9. Explain the basic principles of MR Elastography based on shear wave propagation	3	2	3	2	2	3	
	IA5K10. Explain how elastograms are generated and analysed.	2	3	4	1	3	2	
	IA6K3. Discuss qualitative and quantitative methods to analyse Dynamic Contrast Enhancement (DCE) data for enhancement pattern in prostate.	2	3	3	2	3	2	Majority of radiographers (60%) rejected 4 statements in IA6 (*Assumes responsibility for the planning and execution of MRI*

	IA6K4. Differentiate between methods for MR-guided prostate biopsy (transrectal interventional 'in-bore' MR; fusion biopsy with TRUS).	2	3	4	1	3	2	*male pelvis including prostate and rectum*). Again, there is a possibility that radiographers see themselves more involved in operational aspects of MRI, and patient care rather than post-processing.
	IA6S5. Select an adequate temporal resolution to achieve time intensity curves for prostate imaging	2	3	5	0	3	2	
	IA6S6. Display and analyse coloured maps of DCE data superimposed on T2W images.	2	3	5	0	3	2	
	IA7K2. Explain native imaging and MR angiography for Uterine Artery Embolization (UAE).	2	3	3	2	4	1	
	IA8K6. Explain qualitatively rotating k-space acquisition techniques to reduce motion artefacts.	3	2	4	1	1	4	IA8K6 (*Explain qualitatively rotating k-space acquisition techniques to reduce motion artefacts*) was heavily rejected by medical physicists (80%) and got moderate consensus from radiographers. K-space knowledge is important for radiographers as it describes how data is handled. Perhaps Medical Physicists are aware that K-space is difficult to understand and hence should not be attempted by radiographers.
	IA9K1. Define tissue permeability.	3	2	4	1	3	2	7 statements were rejected from IA9 competence (*Shares responsibility for the planning and*
	IA9K2. Explain how blood-brain barrier	4	1	3	2	3	2	

	permeability can be estimated from temporal measurements of contrast agent concentration							*execution of MRI sequences requested for the assessment of change in tumour burden as a measure of treatment response or tumour progression*). IA9S1 and IA9S2 was rejected by majority of radiographers and medical physicists. Majority of radiologists (60%) rejected IA9K4 – application of arterial spin labelling. Medical physicists rejected the majority of statements in this competence.
	IA9K4. Explain the application of arterial spin labelling (ASL) to tumour blood flow	5	0	2	3	3	2	
	IA9K5. Explain the application of MR Spectroscopy (MRS) as applied to tumour progression and treatment follow-up	4	1	4	1	2	3	
	IA9K6. Explain the application of Chemical Shift Imaging (CSI) as applied to tumour progression and treatment follow-up	4	1	4	1	2	3	
	IA9S1. Select the appropriate TE to maximize the visibility of metabolites as applied to tumour progression and treatment follow-up	2	3	5	0	2	3	
	IA9S6. Select spin labelling duration time and prescribe labels to acquire pseudo continuous ASL images	2	3	5	0	2	3	
	IA10K5. Explain qualitatively segmented k-space GRE acquisition (multiple shot imaging)	3	2	3	2	4	1	
	IA10K8. Explain quantitative analysis of functional dynamic imaging.	4	1	3	2	3	2	
	IA10K9. Explain T1 mapping and the various modified look-locker acquisitions (MOLLI).	3	2	3	2	2	3	
	IA11K3. Explain the relevance of Gradient Moment Nulling and Magnetization Transfer in	3	2	3	2	3	2	

	MRA techniques							
	IA11S6. Select Gradient Moment Nulling and Magnetization Transfer to increase the conspicuity of vessels	3	2	4	1	3	2	
	IA14K4. Demonstrate sufficient knowledge of oncology planning software to be an effective member of the planning team	4	1	3	2	3	2	
	IA15K2. Explain principles of MRI-based attenuation correction (segmentation-based AC and atlas-based AC)	2	3	3	2	3	2	Majority of Radiographers (60%) rejected IA15K2 which also got moderate consensus from radiologists and medical physicists
	IA15K4.Explain the specific characteristics of MRI-PET imaging software	5	0	2	3	3	2	Majority of Radiologists (60%) rejected IA15K4 (*Explain the specific characteristics of MRI-PET imaging software*). This statement also received moderate consensus by medical physicist. However, radiographers favoured this knowledge statement possibly since they expect that such modality would also be operated by a team of MRI radiographers and Nuclear Medicine radiographers.

	FM3K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with physicists in the in the development of referral guidelines and learning outcomes for referrers	2	3	3	2	4	1	Majority of radiographers (60%) rejected all statements in Facility Management competence FM3 (*Participates in a multi professional group in the development of referral guidelines and the certification of MRI referrers in order to grant referring privileges*) possibly pointing towards a non-participatory stance with other professions in such competences. This non-participatory stance by the same professional group was also noted at the 80% and 90% level of consensus.
	FM3S1. Liaise with Medical Physicists in the in the development of referral guidelines and learning outcomes for referrers	2	3	4	1	4	1	
	FM5K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in the procurement of MRI scanners and associated medical devices.	3	2	3	2	4	1	
	Median	3		4		3		

*Table 7. 3 - Analysis of Knowledge and Skill statements rejected at the **70%** consensus level by profession.*

7.6 Discussion

The primary objective of this study was to reach consensus on the biomedical physics learning outcomes required by MRI radiographers. By starting with a list of MRI competences developed in an earlier objective, this study described a systematic research-based process of learning outcome development and validation, as one of the primary steps of curriculum development outlined by Lee et al (2013) and Huyghe et al (2013). For a relatively new content domain such as MRI Physics, formulation of learning outcomes presents an important challenge. The researcher believes that this is the first time that an inventory of MRI physics learning outcomes has been developed using a comprehensive, systematic, multi-stakeholder, research-based collaboration and the process can be useful in other domains containing similar content.

Validation by consensus was emphasized at every step of the process. First, the instrument which served as basis for external validation was based on several data sources: local service portfolio, clinical care pathway and competence profile which were all developed by consensus with multistakeholder groups. Second, the content was validated by a group of SMEs. The web based survey method can be an important source of validity evidence in medical imaging education. One-to-one interviews could have been used, but the use of a web survey was the preferred method, particularly in view of the financial difficulties involved in meeting many (including foreign) experts individually. The use of a web survey provided an acceptable solution to the problem of geographical distances and resulted in a group of participants who hailed from different countries. In addition, because the survey is anonymous, there is less risk that strong personality biases the input from other colleagues or that a group from any institution dominates the debate.

The consensus method of validation has its advantages but also its weaknesses. At stringent levels of consensus K and S that may be considered important by majority of participants may end up eliminated if a few participants disagree. With this in mind, the researcher chose 70% as the cut-off criterion for level of consensus for the final suggested version of the inventory. The inventory was also analysed at the 80%, and 90% levels of consensus for situations when CPD time is limited.

At 70% level of consensus, the expert group rejected 43 statements (13%) - 35 Knowledge and 8 skills, from the initial blueprint inventory.

Consensus at the 70% level (except for one knowledge statement on chemical shift imaging) was obtained for the complete set of Fundamental MRI Physics learning outcomes with the experts commenting that at this level radiographers should also demonstrate basic knowledge of DWI and SWI. Other comments in this section referred to the fact that some MRI procedures such as daily QC should also be considered as fundamental. In addition, all radiographers should be able to explain and identify the various types of artefacts and these should be correctly identified by the MRI radiographer undergoing training. Additional suggested fundamental knowledge included awareness of gadolinium deposition in the dentate nuclei after repeated administration of linear GBCA although whether this should fall under physics was debateable. This clearly shows that the knowledge and skills in this section are indeed generic to all competences and could be used as an introductory course for radiographers starting their MRI careers.

Of note is that the majority of statements that were rejected in the Image Acquisition key activity all focused on advanced applications specifically Diffusion Weighted Imaging, Diffusion Tensor Imaging, Time-intensity curves, Spectroscopy, Kinematic Imaging, specific cardiac sequences, ultrashort TE, cartilage imaging, Spin labelling imaging and MRI-PET. This could mean that knowledge and skills about procedures which currently are not yet routine practice were being side lined in favour of focusing more on knowledge and skills required for the more common services.

In the Image Acquisition section, statements related to the not so common use of advanced applications such as Diffusion Tensor Imaging, Kinematic MRI, MR elastography, MR Spectroscopy, Arterial Spin Labelling, Uterine Arterial Embolization, Chemical shift imaging, T1 mapping, Pharmacokinetics and MRI guided prostate biopsy were not accepted even at the 70% level. The comments from medical physicists also indicated that the underlying physics concepts are too advanced and the participants commented that they are not really necessary for radiographers to know '*Some of the topics here are very advanced and/or specialised I don't think necessary for the radiographer (medical physicist)* ', '*These are very advanced topics. I would only expect the radiographer to be conversant with practical aspects (medical physicist)'*. Other statements which referred to generation and analysis of time-intensity curves, MR spectroscopy metabolites maps, liver iron maps, fat in liver were also rejected with comments suggesting that radiographers should not be involved in analysis '*…produce but not analyse, be aware if it (maps) do not look correct- radiologist', display and be able to see good quality from bad but not to analyse the study (radiologist)*.

There was only one competence (FM3) the K and S of which were totally rejected (FM3K1 and FM3S1) by radiographers at 70%. This was related to facility management specifically about knowledge of MRI physics terminology to liaise with medical physicists in the development of referral guidelines and learning outcomes. The main comment was that '*radiographers should focus on the patients imaging experience as opposed to the before and after the journey*'. Another comment was that '*Referral guidelines are clinically based and the liaison is more appropriate to be with radiologists rather than medical physicists'*. These comments seem to indicate that participants expected the radiographer as focusing on the image production rather than playing a key role at the interface between patient and technology, and being the pivot between referrers, patients and radiologists. Radiographers were identified as key players in the implementation of referral guidelines (Remedios et al., 2014). The comments also indicate that some participants do not appreciate sufficiently the clinical contribution of medical physicists. This is quite surprising because in a workshop on the development of European referral guidelines it was commented that the design of guidelines should involve multidisciplinary collaboration. However even more surprising is the fact that medical physicists, who are in a position to contribute towards such issues as SAR safety levels and image quality reference dose level were not included in this workshop.

Regarding the statements rejected at the 70% level of consensus, if one considers the inventory in its totality and compares the medians of the number of participants opting for a yes by professional group, less radiographers (median = 3) and Medical Physicists (median = 3) agreed with statements than Radiologists (median = 4) points to the possibility that radiologists expect a higher level of knowledge and skills from radiographers than radiographers themselves.

At 80% an additional 29 statements were rejected by the expert group. There was no statistical difference between professions, however of note is that again the majority of statements that were rejected in the Image Acquisition key activity all focused on advanced applications specifically Diffusion Weighted Imaging, Diffusion Tensor Imaging, Spectroscopy, Kinematic Imaging, cartilage imaging and Spin labelling imaging (IA9S7) which incidentally was the only statement rejected by majority of medical physicists This could further confirm that knowledge and skills about procedures which currently are not yet routine were being side-lined in favour of focusing more on knowledge and skills required for the more common services.

At 80% and higher the researcher noted that further K & S statements on the role of the radiographer as participant in the development of standard operating procedures, development of education material to other stakeholders, and development of local and national benchmarks were rejected more often by radiographers than medical physicists or radiologists. Clearly this shows that regular inter-professional collaboration is lacking, and that current practice (and not what is desirable by the year 2020), could have influenced some of the participants. Notwithstanding this, comments from the radiography group referred to statements that would require collaboration with radiologists. For example, in SRM1S4 ('Collaborate with medical physicists in the setting up of a local code of practice') one radiographer commented that '*the setting up of a local code of practice needs to be set up in collaboration within a multidisciplinary team and not just between radiographers and medical physicists*'.

Team work requires professionals to have a shared professional perspective, based on the understanding of common purpose and the pooling of knowledge and expertise and the facilitation of collaboration (Nancarrow et al., 2013). Of interest in this process was the identification of differences between professional groups when looking at aspects of the MRI care pathway. For example, there was more positivity among medical physicists and radiologists than radiographers towards knowledge and skill statements that allow liaising with other healthcare professionals to audit the effectiveness of the MRI care pathway, and to develop standard operating procedures and setting of quality criteria. Of further interest, the majority of radiographers and medical physicists rejected knowledge and skill statements related to physics aspect of advanced applications close to role boundaries. On the other hand, radiologists indicated that radiographers should be knowledgeable and skilled to assume responsibility across all key activities. This agreement or disagreement between the main stakeholders is of importance when developing CPD learning outcomes because it can help clarify role expectations and develop a shared understanding of which professional group might be best placed for a particular competence. As a result team work can be further enhanced with clarity around responsibilities allowing team members to communicate better towards improved decision making (Firth-Cozens, 2001).

At 90% level of consensus, 103 additional statements were rejected, the majority in the key activities of Image Acquisition, Quality Assurance and Service Unit Management. Some knowledge statements on basic laws of electromagnetism, and parallel imaging and basic optimization skills of scanning protocols were rejected. This was quite surprising as the researcher did not expect that majority of radiographers would state the modification of scanning parameters or the modification of the scanning protocol is not required. The researcher is of the opinion that optimization of the scanning protocols is crucial for quality images and MRI safe operation (Woodward, 2000). Despite this, at the 90% level of consensus the Fundamental Biomedical Physics knowledge and skills GENERIC to ALL competences still achieved a high content validation (76% of statements) confirming that this section could be used on its own as an introductory CPD to entry level radiographers in MRI

7.7 Conclusion

In this objective, a comprehensive and validated inventory of MRI biomedical physics learning outcomes has been developed using validated data originating from the local MRI setting using a formal research process. Content validation by consensus was central to this objective and was further strengthened through the collaboration from an international panel of experts, having equal representation from the three professions directly involved in the MRI care pathway. In addition to a good response rate this panel composition allowed qualitative comparison between the groups. The inventory of learning outcomes was analysed at various levels of consensus and was also divided into two sections – Fundamental biomedical physics Generic to all competences and Additional biomedical physics specific to each individual competence. The fundamental biomedical physics achieved a high content validation indicating that it could be used on its own as an introductory CPD to entry level radiographers in MRI and if time permits the Fundamental physics learning outcomes should ideally be included in the undergraduate radiography curriculum. In Image Acquisition statements related to rarely used advanced applications were rejected at the 70% level of consensus. In the other key activities, there was only one competence statement on development of referral guidelines the knowledge and skills of which was rejected at the 70% level of consensus. The comparative results between the three professions, in general indicate that medical physicists and radiologists are more open towards inter-professional collaboration than radiographers. The results also point to the possibility that radiologists expect a higher level of knowledge from radiographers.

It is important to note that although this study targeted physics knowledge and skill learning outcomes for MRI radiographers from a methodology perspective the process used to develop and validate the learning outcomes inventory is sufficiently generic to be easily adapted to the development of curricular content in all other healthcare professions.

The next chapter takes a reflexive stance to conclude this journey.

Chapter 8.0: Conclusion, reflections, limitations and recommendations

8.1 Introduction

This chapter presents a summary of the main conclusions from the study, followed by reflections on the study, a discussion of the limitations of the study and recommendations for future research.

The technological expansion and consequent increased range of MRI procedures has resulted in a greater service demand on medical imaging departments. In addition, high quality CPD courses are becoming increasingly expensive and time off for radiographers is becoming progressively limited owing to high workloads. It is thus important that CPD time is optimized by ensuring that content reflects more closely the specific learning needs of radiographers for whom it is designed and the healthcare needs of the local population. This research used a sequential mixed method strategy to develop an inventory of MRI biomedical physics learning outcomes for radiographers working in Malta.

Through a process of multi-stakeholder collaboration, the first objective was to look at the local setting and develop a portfolio of current MRI services and those that are expected to be in demand by the year 2020. The second objective was to optimize an MRI care pathway in order to identify those steps which are essential to deliver a consistently effective and safe service. The researcher also looked at the international MRI scene and surveyed 6 major English-speaking countries to identify elements of good practice in the structure of MRI competence profiles. The data from these three objectives was used to develop the first local MRI competence profile. The MRI competence profile formed the basis upon which the researcher then developed the MRI physics learning outcomes inventory.

8.2 Summary of conclusions

The following are the main conclusions of the study:

Objective 1: portfolio 2020 service portfolio was developed and validated. The MRI stakeholder experts agreed that the present MRI educational provision to all professions should be quality assured and that it should also be made available to MD and non-MD referrers. MRI legislation education should be also made available to all healthcare professionals whilst the public should be provided with MRI information utilizing social media and healthcare fairs. Participants expected that current services will remain and an increase is expected as MRI is fast becoming the gold standard for a significant number of pathological conditions. Scanning protocols should be optimized to better answer the clinical question with respect to the individual patient.

A one size fit all protocol is not an option. New services that were forecasted in 2013 when this objective was being conducted have since been introduced and are now in place. These include cardiac MRI, prostate MRI, MR guided biopsies of the breast, MR enterography, liver elastography and the installation of a 3T MRI scanner. Referral guidelines, despite the high level of agreement and consensus are not yet in place and this situation is once again resulting in long waiting lists. The majority of participants agreed that outsourcing should only be considered after all available options have been exhausted. The results of this objective were published in the article 'Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020' (Castillo et al., 2015b).

Objective 2: This objective addressed the optimization of the local MR care pathway by a multistakeholder panel using the well-established nominal group technique. Ten optimization related issues were identified and ranked in order of decreasing importance. Highest ranking scores (rank score > 70) were assigned to patient safety, education of referrers and use of quality criteria. The NGT method also brought forward novel themes in particular the need for a radiographer's technical report and the need for referrers to indicate pain levels of patients. The results of this objective were published in the article 'Optimizing a magnetic resonance care pathway: A strategy for radiography managers' (Castillo et al., 2015a).

Objective 3: In this study of competence profiles in English-speaking countries it was found that New Zealand, Canada, United Kingdom and United States have well established national competence profiles and qualification and certification frameworks whilst Australia, and Ireland do not have national competence profile. All countries have a registration process which in some cases (Canada and the US) is based on a national examination. In Australia, United Kingdom and Ireland there is no registration specific to MRI. The results of this objective were published in the article 'An international survey of MRI qualification and certification frameworks with an emphasis on identifying elements of good practice' (Castillo et al., 2017)

Objective 4: This study developed and validated an MRI competence profile for radiographers that would be sufficient to deliver the MRI service portfolio and MRI care pathway in Malta in 2020 identified in objective 1 and 2 and based on good practices identified in objective 3. A competence profile blueprint developed from the three earlier studies was reviewed by qualified subject matter experts who had both clinical and pedagogical expertise. The final list of competences was validated by a multi-stakeholder MRI expert group using a Delphi technique. Level of agreement was assessed as the median value on a 6-point Likert scale ranging from 1 (complete disagreement) to 6 (complete agreement), the level of acceptance was quantified as the median whilst the level of consensus was assessed using the interquartile range (IQR). Competences in the final profile achieved levels of acceptance ≥5 and a level of consensus IQR≤1.

The results of this objective were presented at the European Congress of Radiology in Vienna and awarded best scientific paper presentation within the topic Radiographers:

'Validation of a competence profile for MR radiographers using a formal research process' (Castillo et al., 2016).

Objective 5: In this objective, the researcher developed and validated an inventory of MRI physics knowledge and skills learning outcomes to support the competence profile developed in Objective 4. The final inventory consisting of 324 knowledge and skills statements was structured in two parts: a set of Fundamental knowledge and skills expected of all MRI radiographers and a second set of Additional knowledge and skills specific to each competence within the competence profile. At 70% level of consensus, all Fundamental MRI Physics learning outcomes except for one knowledge statement on chemical shift imaging were accepted. In the case of Additional knowledge and skills, some learning outcomes falling under the not so commonly used advanced applications such as Diffusion Tensor Imaging, Kinematic MRI, MR elastography, MR Spectroscopy, Arterial Spin Labelling, Uterine Arterial Embolization, Chemical shift imaging, T1 mapping, Pharmacokinetics and MRI guided prostate biopsy were not accepted. The comments indicated that the underlying concepts are too advanced, with participants expecting the radiographer to be conversant only with practical aspects. Other statements which referred to generation and analysis of time-intensity curves, MR spectroscopy metabolites maps, liver iron maps and fat in liver were also rejected. The inventory was also validated at the 80% and 90% level of consensus to provide a guideline for situations when CPD time is limited. In such situations radiography educators should concentrate on those knowledge and skills with such levels of consensus.

In this study, the researcher has demonstrated that high quality, practice-oriented development of learning outcome inventories for CPD is possible provided this is based on a formal research process.

Within this context the researcher is also confident in stating that the validated inventory can:

1. Inform the workforce with the physics knowledge and skills required before planning new MRI services.

2. Assist those healthcare institutions starting an MRI service.

3. Be used by those institutions with established MRI services as a benchmark against which expectations about performance and qualifications can be better assessed.

4. Inform competence assessment frameworks to facilitate progression of skills and shape lifelong learning.

The results of this objective will be submitted for publication following October 2017.

8.3 Reflections on the study

This PhD project is quite unique in the sense that the literature does not give other instances in which a profession specific competence profile and learning outcomes inventory has been developed and validated using such a comprehensive, multistakeholder and extensive formal research process.

The project took six years to realize. This was mainly attributed to the fact that deep thinking for each objective was required by the researcher to ensure that the adopted methodology is valid for the purpose of addressing the objectives. In addition, the low number of articles in the area meant that one was continuously treading on new ground. Now that a validated competence profile (possibly the first one in Europe) and associated inventory of MRI physics learning outcomes based on KSC have been developed, the methodology can be utilized for other modalities and the results can be obtained in less time. It is expected that six months would be needed to develop a competence profile and another six months to develop and validate a learning outcomes inventory. A team with fulltime leadership would manage to do this in less time.

8.4 Limitations of the study

Research design limitations: The methodological limitations of the study arise from limitations of the main research methodology used. Practitioner research has the major advantage that it is carried out by 'insider' researchers who would have a very good working knowledge of the research context. However, it has been criticized as being biased in favour of the profession carrying out the research. This bias was minimized by having a multidisciplinary ABoE and by including all the relevant stakeholders which included medical physicists, radiographers, radiologists, educators, vendors, nurses and healthcare policy makers in the research process.

Consensus decision-making methods are often criticized for not being as effective when participants in the group engage in turf protection and thus block the process that could lead to change. Thankfully in this study the open and inclusive multi-stakeholder approach adopted made this a rarity. In fact, it was only evident during this study in one particular instance during the development of the competence profile. The difference of opinion in 5 of the 43 competences concerned between radiographers, medical physicists and radiologists was not detrimental to the study, but it demonstrates that issues resulting from inter-professional relationships sometimes do surface.

8.5 Recommendations for future research

The following are some suggestions for future research.

Due to its superior soft tissue contrast and no ionizing radiation, paediatrics MRI procedures are becoming more frequent. One of the biggest challenges of paediatric MR imaging is the acquisition of high-quality diagnostic images, as it requires the infant or child to keep still for a long period of time. This is not always possible and sedation / play techniques would be required. Moreover, commercial MR machines and protocols are designed for adult practice and currently, children are imaged in units that are rarely furnished for the paediatric population. In addition to this aesthetic limitation, the structures that need to be examined are generally small and high resolution imaging necessitates optimized scanning protocols (Saunders et al., 2007). Therefore, further study is required to optimize the paediatric MRI care pathway in order to improve further the competence profile and associated knowledge and skills with respect to paediatric imaging.

The results in objective 3 indicate that the majority of competence profiles are targeted towards the entry level MRI radiographer. Only New Zealand previously had three levels of skills. The competence profile developed in this study includes several competences that are meant for higher level of expertise. A study is required to structure the competence profile along a novice-to-expert continuum and ideally referenced directly to a national qualification and certification framework in order to allow better assessment of the level of expertise. In addition, it is also being recommended that the study should identify ideal methods of competence assessment.

It was also noted that there were no documents from regulatory boards regarding PET/MRI. This hybrid modality is still in its infancy and the only document that the researcher came across was an initial set of recommendations by the Section of Magnetic Resonance Technologists of the Society of Nuclear Medicine and Molecular Imaging Technologists (Gilmore et al., 2013). Within this context, it is being recommended to carry out a study to determine how existing PET/MRI units are operating and what additional competences would be required by radiographers.

In Objective 5, the radiography expert group showed moderate consensus towards knowledge and skills statements that are necessary for MRI radiographers to participate in the development of referral guidelines, standard operating procedures, auditing, and procurement. In contrast radiologists and medical physicists seemed to be more open towards inter-professional collaboration. This was also evident in other competence statements. Findings from an investigation into inter-professional education at the Faculty of Health Science (Bonello, 2016) indicates that professionals expressed concerns about the challenge of identifying and maintaining professional territories and boundaries, and about the possibility that IPE could manifest in the dilution of some health care professions. In particular the represented professions were resistive towards inter-professional education (Bonello, 2016). The absence of inter-professional education could be one of the reasons for the radiographer stance and therefore it is being recommended to investigate the level of inter-professional collaboration between medical physicists, radiologists and radiographers and identify the barriers, if any, that are contributing to lack of participation of radiographers in some key activities.

This overall approach to the development of learning outcomes for MRI as a subspecialty is comprehensive and based on several sources of evidence thus enhancing internal validity. The researcher believes that the comprehensive sequential mixed methodology used in this study is generic enough to be used in developing competence profiles and associated learning outcomes for other medical imaging sub-specializations. The delivery of the MRI physics curriculum also necessitates another study to identify the most effective and efficient systems of delivering the learning outcomes to students and radiographers without affecting service delivery. In addition, further validity of the physics learning outcomes inventory could be sought by analysing student feedback following the implementation of the MRI physics curriculum.

The diverse competence profiles in some major English-speaking countries suggests that competences profiles that may be necessary in the various European small nations may also vary. An initial short pilot study by the researcher to determine the feasibility of evaluating whether the competence profile developed in this study was externally valid also to the other small states in Europe indeed indicated that this may be the case. Although response was only obtained from two countries out of the eight small states (Luxembourg and Cyprus), the indications are that the competence profile was not entirely valid for their context. A multi-national study of MRI competence profiles for small nation states would be interesting as it would indicate factors (e.g., geographical, social, historical) which influence competence profiles.

8.6 Conclusion

In this study, the researcher has provided radiographer managers and educators with a methodology which they can utilize to develop practical, clinically oriented CPD programmes for radiographers. The increase in the scope of MRI practice seems to lead towards a redefinition of practice that includes aspects of roles once thought to be the sole responsibility of other healthcare practitioners. On the other hand, this study has also shown that radiologists and medical physicists are in favour of multi-disciplinary collaboration and Maltese MRI radiographers are now at a cross-road to make the leap forward.

References

Ahmed, H. U., Kirkham, A., Arya, M., Illing, R., Freeman, A., Allen, C., & Emberton, M. (2009). Is it time to consider a role for MRI before prostate biopsy? *Nature Reviews Clinical Oncology, 6*(4), 197-206.

Ahmed, J. U. (2010). Documentary research method: New dimensions. *Indus Journal of Management & Social Sciences, 4*(1), 1 - 14.

Akimoto, T., Caruana, C. J., & Shimosegawa, M. (2009). A qualitative comparative survey of First Cycle radiography programmes in Europe and Japan. *Radiography, 15*(4), 333-340.

Alberta College of Medical Diagnistic and Therapeutic Technologists. (2015). Registration. Retrieved from http://acmdtt.com/registration/general-registration/

Allen, I. E., & Seaman, C. A. (2007). Likert scales and data analyses. *Quality progress, 40*(7), 64.

Alsharif, W., Davis, M., McGee, A., & Rainford, L. (2017). An investigation of Saudi Arabian MR radiographers' knowledge and confidence in relation to MR image-quality-related errors. *Radiography, 23*(2), e27-e33.

Alvarez-Linera, J. (2008). 3T MRI: advances in brain imaging. *European journal of radiology, 67*(3), 415-426.

American Registry of MRI Technologists. (2015). Job Analysis Survey. Retrieved from http://www.armrit.org/pdf/ECSurveyTextWeb.pdf

American Registry of Radiologic Technologists. (2009). Content specification for the examination in magnetic resonance imaging. Retrieved from https://www.arrt.org/docs/default-source/discipline-documents/mri--primary/mri-content-specifications.pdf?sfvrsn=16

American Registry of Radiologic Technologists. (2015a). Initial ARRT certification and registration. Retrieved from https://www.arrt.org/Certification

American Registry of Radiologic Technologists. (2015b). Practice Analysis. Retrieved from https://www.arrt.org/practice-analysis/

American Registry of Radiologic Technologists. (2015c). Task Inventory - Magnetic Resonance Imaging. Retrieved from https://www.arrt.org/docs/default-source/discipline-documents/mri--primary/mri-task-inventory.pdf?sfvrsn=14

American Society of Radiologic Technologists. (2010). Magnetic Resonance section of the Practice Standards of Medical Imaging and Radiation Therapy.

Appleton, J. V., & Cowley, S. (1997). Analysing clinical practice guidelines. A method of documentary analysis. *Journal of Advanced Nursing, 25*(5), 1008-1017.

ASRT, SMRT, & AEIRS. (2008). Magnetic Resonance Curriculum. Retrieved from http://www.ismrm.org/smrt/mr_curriculum08.pdf

Australian Institute of Radiography. (2010). Education Policies. Retrieved from http://www.air.asn.au/cms_files/10_Publications/policies_guidelines/education_policies_dec2010.pdf

Australian Institute of Radiography. (2013). Professional practice standards for the accredited practitioner. Retrieved from http://www.air.asn.au/cms_files/10_Publications/policies_guidelines/pps_air_dec2013.pdf

Australian Institute of Radiography. (2014a, December 2014). MIAP1 Policies and Procedures. Retrieved from http://www.air.asn.au/cms_files/05_Accreditation/mri/mri_policies_procedures_final_dec14.pdf

Australian Institute of Radiography. (2014b). Pathway to Advanced Practice. Retrieved from http://www.air.asn.au./advanced.php

Bailie, J. L. (2011). Effective online instructional competencies as perceived by online university faculty and students: A sequel study. *Journal of Online Learning and Teaching, 7*(1), 82-89.

Barnes, R., Lawton, L., & Briggs, D. (1994). Clinical benchmarking improves clinical paths: experience with coronary artery bypass grafting. *The Joint Commission journal on quality improvement, 20*(5), 267-276.

Barnett, R., & Coate, K. (2004). *Engaging the curriculum in higher education*: McGraw-Hill Education (UK).

Beaudin, B. P. (1999). Keeping online asynchronous discussions on topic. *Journal of Asynchronous Learning Networks, 3*(2), 41-53.

Benner, P. (1982). From Novice To Expert. *AJN The American Journal of Nursing, 82*(3), 402-407.

Berg, B. L. (2004). *Methods for the social sciences*. United States of America.: Pearson Education Inc, .

Biemans, H., Nieuwenhuis, L., Poell, R., Mulder, M., & Wesselink, R. (2004). Competence-based VET in the Netherlands: background and pitfalls. *Journal of vocational education and training, 56*(4), 523-538.

Blachar, A., Tal, S., Mandel, A., Novikov, I., Polliack, G., Sosna, J., Freedman, Y., Copel, L., & Shemer, J. (2006). Preauthorization of CT and MRI Examinations: Assessment of a Managed Care Preauthorization Program Based on the ACR Appropriateness Criteria® and the Royal College of

Radiology Guidelines. *Journal of the American College of Radiology, 3*(11), 851-859.

Blackmore, C. C., Mecklenburg, R. S., & Kaplan, G. S. (2011). Effectiveness of clinical decision support in controlling inappropriate imaging. *Journal of the American College of Radiology, 8*(1), 19-25.

Blamire, A. (2008). The technology of MRI—the next 10 years? *The British journal of radiology, 81*(968), 601-617.

Blundell EG. (2012). *Document analysis as a qualitative research technique in assessing oral health policy*. Canada. https://www.dal.ca/content/dam/dalhousie/pdf/dentistry/ICOH2010/DocAnalysisSchool.pdf

Bodil, T. A., Bengt, F., Carina, E., & Åsa, B. A. (2008). Radiographers' areas of professional competence related to good nursing care. *Scandinavian Journal of Caring Sciences, 22*(3), 401-409.

Bolejko, A., Sarvik, C., Hagell, P., & Brinck, A. (2008). Meeting patient information needs before magnetic resonance imaging: development and evaluation of an information booklet. *Journal of radiology nursing, 27*(3), 96-102.

Bologna Working Group. (2005). A Framework for Qualifications of the European Higher Education Area. Retrieved from http://www.bologna-bergen2005.no/Docs/00-Main_doc/050218_QF_EHEA.pdf

Bonello, M. (2016). *Conceptualising the Development and Delivery of Interprofessional Health Care Education in Malta.* (PhD thesis), University of Brighton, United Kingdom.

Bradfield, O. M. (2009). GP access to MRI: the Australian reality. *Australian Health Review, 33*(2), 311-314.

Brailsford, S., & Vissers, J. (2011). OR in healthcare: A European perspective. *European Journal of Operational Research, 212*(2), 223-234.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Brix, G., Nagel, H., Stamm, G., Veit, R., Lechel, U., Griebel, J., & Galanski, M. (2003). Radiation exposure in multi-slice versus single-slice spiral CT: results of a nationwide survey. *European radiology, 13*(8), 1979-1991.

Brody, A. S., Frush, D. P., Huda, W., & Brent, R. L. (2007). Radiation risk to children from computed tomography. *Pediatrics, 120*(3), 677-682.

Burgess-Allen, J., & Owen-Smith, V. (2010). Using mind mapping techniques for rapid qualitative data analysis in public participation processes. *Health Expectations, 13*(4), 406-415.

Busch, H. (2010). [Benchmarking of radiological departments--starting point for successful process optimization]. *Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin, 182*(3), 221-228.

Calamante, F., Ittermann, B., Kanal, E., & Norris, D. (2016). Recommended responsibilities for management of MR safety. *Journal of Magnetic Resonance Imaging, 44*(5), 1067-1069.

Campbell, S. M., Roland, M. O., & Buetow, S. A. (2000). Defining quality of care. *Social Science & Medicine, 51*(11), 1611-1625.

Canadian Association of Medical Radiation Technologists. (2008). Magnetic Resonance Competency Profile. Ontario.

Canadian Association of Medical Radiation Technologists. (2014). Magnetic Resonance Competency Profile. Retrieved from http://www.camrt.ca/wp-content/uploads/2015/03/MR-profile-Final.pdf

Canadian Association of Medical Radiation Technologists. (2015). Best Practice Guidelines. Retrieved from https://ww2.camrt.ca/bpg/

Caruana C and Castillo J. (2010). *MRI Physics Education For Diagnostic Radiographers - An Initial Study*. Paper presented at the IV European Conference of Medical Physics on Advances in High Field Magnetic Resonance Imaging, Udine, Italy. http://www.csfm.cz/userfiles/file/Udalosti2010/IV_ECMP_Udine2010_Scientific%20programme.pdf

Caruana, C., Wasilewska-Radwanska, M., Aurengo, A., Dendy, P., Karenauskaite, V., Malisan, M., Meijer, J., Mornstein, V., Rokita, E., & Vano, E. (2009). The role of the biomedical physicist in the education of the healthcare professions: An EFOMP project. *Physica Medica, 25*(3), 133-140.

Caruana, C. J. (2009). *Biomedical Physics Education for Diagnostic and Therapeutic Radiographers in Europe-A Review.* Paper presented at the World Congress on Medical Physics and Biomedical Engineering, Munich, Germany.

Caruana, C. J., & Plasek, J. (2006a). An inventory of biomedical imaging physics elements-of-competence for diagnostic radiography education in Europe. *Radiography, 12*(3), 189-202.

Caruana, C. J., & Plasek, J. (2006b). *A SWOT audit for the educator role of the biomedical physics academic within Faculties of Health Science in Europe.* Paper presented at the Modelling in Physics and Physics Education, Amsterdam, Netherlands.

Cases, A. A., Pedro-Botet, M. J., Pascual, F. V., Barrios, A. V., Pintó, S. X., Ascaso, G. J., Millán, N.-C. J., & Serrano, C. A. (2016). Delphi consensus on the diagnosis and management of dyslipidaemia in chronic kidney disease patients: A post hoc analysis of the DIANA study. *Nefrologia: publicacion oficial de la Sociedad Espanola Nefrologia, 36*(6), 679-686.

Castillo, J., & Caruana, C. (2013). Maltese Radiographers' Attitudes towards Continuing Professional Development: An Initial Study Using Concept Maps. *Journal of Medical Imaging and Radiation Sciences, 45*(1), 37-46.

Castillo, J., Caruana, C., Morgan, P., & Westbrook, C. (2015a). Optimizing a magnetic resonance care pathway: A strategy for radiography managers. *Radiography, 21*(1), e29-e33.

Castillo, J., Caruana, C., Morgan, P., & Westbrook, C. (2015b). Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020. *Radiography, 21*(1), e21-e27.

Castillo, J., Caruana, C., Morgan, P., Westbrook, C., & Mizzi, A. (2016). *Validation of a competence profile for MR radiographers using a formal research process.* Paper presented at the European Congress of Radiology, Vienna, Austria.

Castillo, J., Caruana, C., Morgan, P., Westbrook, C., & Mizzi, A. (2017). An international survey of MRI qualification and certification frameworks with an emphasis on identifying elements of good practice. *Radiography, 23*(1), e8-e13.

Castillo, J., Caruana, C. J., & Wainwright, D. (2011). The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level. *Radiography, 17*(3), 230-234.

Cetina, K. K., Schatzki, T. R., & Von Savigny, E. (2005). *The practice turn in contemporary theory*: Routledge.

Challen, V. (Ed.) (2008). *Overview of the tuning template for radiography in Europe*: Socrates Erasmus.

Chawda, S., Watura, R., & Lloyd, D. (1997). Magnetic resonance imaging of the lumbar spine: direct access for general practitioners. *The British Journal of General Practice, 47*(422), 575.

Cheah, J. (2000). Development and implementation of a clinical pathway programme in an acute care general hospital in Singapore. *International Journal for Quality in Health Care, 12*(5), 403-412.

Choyke, P. L., & Turkbey, B. (2013). The State of Prostate MRI in 2013: Into the Breach: UBM Medica 535 Connecticut Ave, Ste 300, Norwalk, CT 06854 USA.

College of Medical Radiation Technologists of Ontario. (2015). Registration. Retrieved from https://www.cmrto.org/what-we-do/registration/

Colton, S., & Hatcher, T. (2004). *The Web-Based Delphi Research Technique as a Method for Content Validation in HRD and Adult Education Research*. Paper presented at the Academy of Human Resource Development International Conference, Texas, USA.

Corrigan, J. M. (2005). *Crossing the quality chasmBuilding a Better Delivery System*. Washington: The National Academy Press.

CORU. (2013). Radiographers Registration Board - Criteria and Standards of Proficiency Education and Training Programmes http://coru.ie/uploads/documents/Radiographers_Registration_Board_Criteria_and_Standards_of_Proficiency_1.pdf

Cowan, I., Smith, T., Nakabea, P., Ajibulu, O., & Hennessy, O. (2007). Developing the image interpretation skills of South Pacific radiographers: A joint WHO/RANZCR/ISRRT project. *Australasian Radiology, 51*(6), 527-531.

Cowling, C. (2008). A global overview of the changing roles of radiographers. *Radiography, 14*(Supplement 1), 28-32.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (3rd Edition ed.): Sage.

Crisp, J., Pelletier, D., Duffield, C., Adams, A., & Nagy, S. (1997). The Delphi method? *Nursing Research, 46*(2), 116-118.

Crisp , N., & Chen , L. (2014). Global Supply of Health Professionals. *New England Journal of Medicine, 370*(10), 950-957.

Cross, H. (2005). Consensus methods: a bridge between clinical reasoning and clinical research? *International Journal of Leprosy and other Mycobacterial Diseases, 73*(1), 28 - 32.

Cumming, A., & Ross, M. (2007). The Tuning Project for Medicine - learning outcomes for undergraduate medical education in Europe. *Medical Teacher, 29*(7), 636-640.

Cummins, R. A., & Gullone, E. (2000a). *Why we should not use 5-point Likert scales: The case for subjective quality of life measurement.* Paper presented at the Proceedings, second international conference on quality of life in cities.

Cummins, R. A., & Gullone, E. (2000b). *Why we should not use 5-point Likert scales: The case for subjective quality of life measurement.* Paper presented at the Second International Conference on Quality of Life in Cities, Singapore: National University of Singapore.

Cumyn, A., & Harris, I. B. (2012). A comprehensive process of content validation of curriculum consensus guidelines for a medical specialty. *Medical teacher, 34*(8), e566-e572.

Curtis, J. R., Cook, D. J., Wall, R. J., Angus, D. C., Bion, J., Kacmarek, R., Kane-Gill, S. L., Kirchhoff, K. T., Levy, M., & Mitchell, P. H. (2006). Intensive care unit quality improvement: A" how-to" guide for the interdisciplinary team*. *Critical care medicine, 34*(1), 211-218.

Daley, B. J. (2001). Learning and professional practice: A study of four professions. *Adult Education Quarterly, 52*(1), 39-54.

Daley, B. J. (2004). *Using concept maps in qualitative research.* Paper presented at the First International Conference on Concept Mapping, Pamplona Spain.

Davies, S., Romano, P. S., Schmidt, E. M., Schultz, E., Geppert, J. J., & McDonald, K. M. (2011). Assessment of a novel Hybrid Delphi and nominal groups technique to evaluate quality indicators. *Health services research, 46*(6pt1), 2005-2018.

Davis, D. C., Beyerlein, S. W., & Davis, I. T. (2005). *Development and use of an engineer profile.* Paper presented at the Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, Portland, Oregon.

Davis, D. C., Beyerlein, S. W., & Davis, I. T. (2006). Deriving design course learning outcomes from a professional profile. *International Journal of Engineering, 22*(3), 439 - 446.

De Vet, E., Brug, J., De Nooijer, J., Dijkstra, A., & De Vries, N. K. (2004). Determinants of forward stage transitions: a Delphi study. *Health education research, 20*(2), 195-205.

De Wilde, J., Grainger, D., Price, D., & Renaud, C. (2007). Magnetic resonance imaging safety issues including an analysis of recorded incidents within the UK. *Progress in Nuclear Magnetic Resonance Spectroscopy, 51*(1), 37-48.

Delamare-Le Deist F., & Winterton J. (2005). What Is Competence? *Human Resource Development International, 8*(1), 27 - 46.

Delbecq, A. L., Van de Ven, A. H., & Gustafson, D. H. (1975). *Group techniques for program planning: A guide to nominal group and Delphi processes*: Scott, Foresman Glenview, IL.

Delp, P., Thesen, A., Motiwalla, J., & Seshardi, N. (1977). Nominal group technique. *Systems tools for project planning*, 14-18.

Dreyfus, S. E. (2004). The five-stage model of adult skill acquisition. *Bulletin of science, technology & society, 24*(3), 177-181.

Eccardt, T. M. (2005). *Secrets of the Seven Smallest States of Europe: Andorra, Liechtenstein, Luxembourg, Malta, Monaco, San Marino, and Vatican City*: Hippocrene Books.

Eckler, U., Gödl-Purrer, B., Hurkmans, E., Igelsböck, E., & Wiederin, C. (2016). A profession going through changes: developing a profile of competencies and learning outcomes. *Physiotherapy, 102*(Supplement 1), e102.

Edgren, G. (2006). Developing a competence-based core curriculum in biomedical laboratory science: a Delphi study. *Medical Teacher, 28*(5), 409-417.

Education and Training in Radiological Protection. (2009). *Transactions.* Paper presented at the 4th International Conference on Education and Training in Radiological Protection, Lisbon, Portugal.

Educause Center for Analysis and Research Working Group. (2015). *A Model Higher Ed IT Service Catalog*. Retrieved from Louisville, CO: php.scripts.psu.edu/users///m/s/msk24/resume_files/ECAR-SC_latest26feb2015.pdf

Emery, D. J., Forster, A. J., Shojania, K. G., Magnan, S., Tubman, M., & Feasby, T. E. (2009). Management of MRI wait lists in Canada. *HealthCare Policy, 4*(3), 76.

European Commission. (2008). The European Qualification Framework for Lifelong Learning (EQF). Retrieved from http://www.ond.vlaanderen.be/hogeronderwijs/bologna/news/EQF_EN.pdf

European Commission. (2012). *Council Directive laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation*. Retrieved from http://ec.europa.eu/energy/nuclear/radiation_protection/doc/2012_com_242.pdf

European Commission. (2014). Radiation Protection 175 GUIDELINES ON RADIATION PROTECTION EDUCATION AND TRAINING OF MEDICAL PROFESSIONALS IN THE EUROPEAN UNION Luxembourg: Directorate-General for Energy Directorate D — Nuclear Safety & Fuel Cycle Unit D.3 — Radiation Protection

European Commission. (2007). *Commission Staff Working Document: TOWARDS A EUROPEAN QUALIFICATIONS FRAMEWORK FOR LIFELONG LEARNING*. Retrieved from

European Federation of Radiographer Societies. (2012). Position Paper on Directive 2004/40/EC The Electromagnetic Fields Directive. Retrieved from http://www.ft.dk/samling/20111/almdel/beu/bilag/83/1071456.pdf

European Federation of Radiographer Societies. (2017). European Qualification Framework (EQF) Level 7 Benchmarking Document. Retrieved from http://efrs.eu/publications/see/2016.11_EFRS_EQF_level_7_Benchmark_(Master)?file=1083

European Parliament and Council. (2008). Recommendation 2008/C 111/01 on the establishment of the European Qualifications Framework for Lifelong Learning. *Official Journal of the European Union 6.5.2008*.

European Parliament and the Council of European Union. (2013). 2013/35/EU The minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields. *2013/35/EU.* Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013L0035&from=EN

European Society of Radiology. (2013). Alliance for MRI - News. Retrieved from http://www.myesr.org/cms/website.php?id=/en/eu_affairs_research/alliance_for_mri/alliance_for_mri_-_news.htm

Evans-Lacko, S., Jarrett, M., McCrone, P., & Thornicroft, G. (2008). Clinical pathways in psychiatry. *Br J Psychiatry, 193*(1), 4 - 5.

Evans-Lacko, S., Jarrett, M., McCrone, P., & Thornicroft, G. (2010). Facilitators and barriers to implementing clinical care pathways. *BMC Health Services Research, 10*(1), 182.

Fazel, R., Krumholz, H. M., Wang, Y., Ross, J. S., Chen, J., Ting, H. H., Shah, N. D., Nasir, K., Einstein, A. J., & Nallamothu, B. K. (2009). Exposure to low-dose ionizing radiation from medical imaging procedures. *New England Journal of Medicine, 361*(9), 849-857.

Ferris, N. J., Kavnoudias, H., Thiel, C., & Stuckey, S. (2007). The 2005 Australian MRI safety survey. *American Journal of Roentgenology, 188*(5), 1388-1394.

Ferris, T. G., Johnson, S. A., Backus, M., Perrin, J., Bates, D. W., & Poon, E. G. (2009). Electronic results management in pediatric ambulatory care: qualitative assessment. *Pediatrics, 123*(Supplement 2), S85-S91.

Filler, A. G. (2010). The history, development and impact of computed imaging in neurological diagnosis and neurosurgery: CT, MRI, and DTI. *Internet Journal of Neurosurgery, 7*(1), 5-35.

Fink, A., Kosecoff, J., Chassin, M., & Brook, R. H. (1984). Consensus methods: characteristics and guidelines for use. *American Journal of Public Health, 74*(9), 979-983.

Firth-Cozens, J. (2001). Cultures for improving patient safety through learning: the role of teamwork. *Quality and Safety in Health Care, 10*(suppl 2), ii26-ii31.

Fitzgerald, T. (2007). Documents and documentary analysis: Reading between the lines. *Research methods in educational leadership and management, 2*, 278-294.

Formosa, M. (2006). *Supporting Family Carers of Older People in Europe-The National Background Report for Malta* (Vol. 2): LIT Verlag Münster.

Franklin, K. K., & Hart, J. K. (2007). Idea generation and exploration: benefits and limitations of the policy Delphi research method. *Innovative Higher Education, 31*(4), 237-246.

Gambescia, S. F. (2006). Best Practices: Syllabus Construction With a Commitment to Shared Governance. *The Journal of Continuing Higher Education, 54*(1), 20-27.

Garland, R. (1991). The mid-point on a rating scale: Is it desirable. *Marketing bulletin, 2*(1), 66-70.

Giannarou, L., & Zervas, E. (2014). Using Delphi technique to build consensus in practice. *Int. Journal of Business Science and Applied Management, 9*(2).

Gill, M. (2008). Promoting independent learning by curriculum design and assessment in a taught postgraduate MRI programme. *Radiography, 14*(3), 238-245.

Gillham, B. (2005). *Research interviewing: The range of techniques*: Open University Press.

Gilmore, C. D., Comeau, C. R., Alessi, A. M., Blaine, M., El Fakhri, G. N., Hunt, J. K. E., Jordan, D. W., King, B. J., Sicignano, A. J., & Stanley, C. T. (2013). PET/MR imaging consensus paper: a joint paper by the society of nuclear medicine and molecular imaging technologist section and the section for magnetic resonance technologists. *Journal of nuclear medicine technology, 41*(2), 108-113.

Grant, J. S., & Davis, L. L. (1997). Selection and use of content experts for instrument development. *Research in nursing & health, 20*(3), 269-274.

Green, B., & Green, B. (2009). *Understanding and researching professional practice*: Sense Publishers Rotterdam.

Greenhalgh, T., Robert, G., Bate, P., Kyriakidou, O., Macfarlane, F., & Peacock, R. (2004). *How to Spread Good Ideas: A systematic review of the literature on diffusion, dissemination and sustainability of innovations in health service delivery and organisation*: London: National Health Service, Service Delivery & Organization Program.

Greiner, A. C., & Knebel, E. (2003). Health professions education: A bridge to quality: Institute of Medicine.

Grey, S. J., Price, G., & Mathews, A. (2000). Reduction of anxiety during MR imaging: a controlled trial. *Magnetic resonance imaging, 18*(3), 351-355.

Grima, N. (2015). Private medical tourism to keep healthcare in Malta free. *Malta Independent*.

Gupta, R. T., Kauffman, C. R., Polascik, T. J., Taneja, S. S., & Rosenkrantz, A. B. (2013). The State of Prostate MRI in 2013. *Oncology, 27*(4), 1.

Hanafin, S. (2004). Review of literature on the Delphi Technique. Dublin: Office of the Minister for Children and Youth Affairs.

Hand, J., Bosmans, H., Caruana, C., Keevil, S., Norris, D. G., Padovani, R., & Speck, O. (2013). The European Federation of Organisations for Medical Physics Policy Statement No 14: the role of the Medical Physicist in the management of safety within the magnetic resonance imaging environment: EFOMP recommendations. *Phys Med, 29*(2), 122-125.

Harden, R. M. (1986). Ten questions to ask when planning a course or curriculum. *Medical education, 20*(4), 356-365.

Harden, R. M. (1999). AMEE Guide No. 14: Outcome-based education: Part 1-An introduction to outcome-based education. *Medical Teacher, 21*(1), 7 - 14.

Harris, E., Young, P. T., McElveny, C., & Pongracz-Bartha, B. (1995). *The shadowmakers: a history of radiologic technology*. Albuquerque, NM: American Society of Radiologic Technologists.

Harvard Graduation School of Education. (2008). Subjectivity. Retrieved from http://isites.harvard.edu/icb/icb.do?keyword=qualitative&pageid=icb.page340908

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing, 32*(4), 1008-1015.

Hawn, C. (2009). Take two aspirin and tweet me in the morning: how Twitter, Facebook, and other social media are reshaping health care. *Health Affairs, 28*(2), 361-368.

Health and Care Professional Council. (2011). Your guide to our standards for continuing professional development. Retrieved from http://www.hcpc-uk.org/assets/documents/10003B70Yourguidetoourstandardsofcontinuingprofessionaldevelopment.pdf

Health and Social Care Professionals Council. (2016). CPD requirements. Retrieved from http://coru.ie/uploads/documents/Final_CPD_framework_document.pdf

HENRE. (2001). Home Page. Retrieved from http://www.henre.co.uk/

Ho, S. S., Kember, D., Lau, C. B., Au Yeung, M. Y., Leung, D. Y., & Chow, M. S. (2009). An outcomes-based approach to curriculum development in pharmacy. *American journal of pharmaceutical education, 73*(1), 14.

Hsu, C.-C., & Sandford, B. A. (2007). The Delphi technique: Making sense of consensus. *Practical assessment, research & evaluation, 12*(10), 1-8.

Hutchings, A., Raine, R., Sanderson, C., & Black, N. (2006). A comparison of formal consensus methods used for developing clinical guidelines. *Journal of health services research & policy, 11*(4), 218-224.

Huyghe, S., Totté, N., & Verhagen, A. (2013). *Building the curriculum in Higher Education: a conceptual framework.* Paper presented at the Proceedings of the Enhancement and Innovation in Higher Education Conference, Glasgow, UK.

Inman, D., Leaver, A., Gage, D., & Miering, P. D. V. (2009). An evaluation of physiotherapy extended scope practitioner (esp) use of MRI in patients presenting with low back pain; a two-centre study. *Journal of Bone & Joint Surgery, British Volume, 91*(SUPP III), 487-487.

Institute for Human and Machine Cognition. (2010). CMAPTOOLS. Retrieved from http://IHMC.US/cmaptools.php

Institute of Medicine. (2001). *Crossing the quality chasm: A new health system for the 21st century*: National Academies Press.

Irish Institute of Radiography and Radiation Therapy. (2014). *Magnetic Resonance Imaging. Guidelines on Best Practice*.

ISRRT. (2004). *Condition for the education of radiographers within Europe*. Retrieved from http://www.isrrt.org/images/isrrt/Education%20Survey%20within%20Europe%20Updated%20Dec%202004.doc

ISRRT. (2005). *Guidelines for the education of entry level professional practice in medical radiation sciences*. Retrieved from www.isrrt.org

Jackson, K. M., & Trochim, W. M. (2002). Concept mapping as an alternative approach for the analysis of open-ended survey responses. *Organizational Research Methods, 5*(4), 307-336.

Johnston, R., & Clark, G. (2005). *Service operations management: improving service delivery*: Pearson Education.

Jones, J., & Hunter, D. (1995). Consensus methods for medical and health services research. *BMJ: British Medical Journal, 311*(7001), 376.

Kanal, E., Borgstede, J. P., Barkovich, A. J., Bell, C., Bradley, W. G., Etheridge, S., Felmlee, J. P., Froelich, J. W., Hayden, J., & Kaminski, E. M. (2004). American College of Radiology white paper on MR safety: 2004 update and revisions. *American Journal of Roentgenology, 182*(5), 1111-1114.

Karpowicz, J., Hietanen, M., & Gryz, K. (2007). Occupational risk from static magnetic fields of MRI scanners. *The Environmentalist, 27*(4), 533-538.

Kaushal, R., Shojania, K. G., & Bates, D. W. (2003). Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review. *Archives of internal medicine, 163*(12), 1409-1416.

Keeling, R. (2006). The Bologna Process and the Lisbon Research Agenda: the European Commission's expanding role in higher education discourse. *European journal of education, 41*(2), 203-223.

Keeney, S., Hasson, F., & McKenna, H. (2006). Consulting the oracle: ten lessons from using the Delphi technique in nursing research. *Journal of Advanced Nursing, 53*(2), 205-212.

Keeney, S., McKenna, H., & Hasson, F. (2011). *The Delphi technique in nursing and health research*: Wiley-Blackwell.

Keevil, S., Gedroyc, W., Gowland, P., Hill, D., Leach, M., Ludman, C., McLeish, K., McRobbie, D., Razavi, R., & Young, I. (2014). Electromagnetic field exposure limitation and the future of MRI. *The British journal of radiology, 78*(935), 973 - 975.

Kern, D. E. (1998). *Curriculum development for medical education: a six-step approach*: JHU Press.

Kirkham, A., Haslam, P., Keanie, J., McCafferty, I., Padhani, A., Punwani, S., Richenberg, J., Rottenberg, G., Sohaib, A., & Thompson, P. (2013). Prostate MRI: Who, when, and how? Report from a UK consensus meeting. *Clinical Radiology, 68*(10), 1016-1023.

Kitzinger, J. (1995). Qualitative research. Introducing focus groups. *British Medical Journal, 311*(7000), 299 - 302.

Lee, A., Steketee, C., Rogers, G., & Moran, M. (2013). Towards a theoretical framework for curriculum development in health professional education. *Focus on Health Professional Education: A Multi-disciplinary Journal, 14*(3), 70 - 83.

Lehnert, B. E., & Bree, R. L. (2010). Analysis of appropriateness of outpatient CT and MRI referred from primary care clinics at an academic medical center: how critical is the need for improved decision support? *Journal of the American College of Radiology, 7*(3), 192-197.

Lennon, R., Glasper, A., & Carpenter, D. (2012). Nominal group technique: its utilisation to explore the rewards and challenges of becoming a mental health nurse, prior to the introduction of the all graduate nursing curriculum in England. *Working Papers in Health Sciences 1*(2), 1-5.

Li, X., Priest, R. A., Woodward, W. J., Tagge, I. J., Siddiqui, F., Huang, W., Rooney, W. D., Beer, T. M., Garzotto, M. G., & Springer, C. S. (2013). Feasibility of shutter-speed DCE-MRI for improved prostate cancer detection. *Magnetic Resonance in Medicine, 69*(1), 171-178.

Linstone, H. A., Turoff, M., & Helmer, O. (1975). *The Delphi method: Techniques and applications* (Vol. 18): Addison-Wesley Publishing Company, Advanced Book Program.

Little, F., Brown, L., Grotowski, M., & Harris, D. (2014). Interprofessional Relationships in Healthcare Practice. In J. Higgs, A. Croker, D. Tasker, J. Hummell, & N. Patton (Eds.), *Health Practice Relationships* (pp. 143-152). Rotterdam: SensePublishers.

Locke, M. (2011). *Physiotherapy Patient Referral to SEM physicians under the Medicare Benefits Schedule*. Retrieved from Australian Physiotherapy Association: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.655.4257&rep=rep1&type=pdf

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing research, 35*(6), 382-386.

Macdonald, E. B., Ritchie, K. A., Murray, K. J., & Gilmour, W. H. (2000). Requirements for occupational medicine training in Europe: a Delphi study. *Occupational and Environmental Medicine, 57*(2), 98-105.

MacKenzie, R., Sims, C., Owens, R., & Dixon, A. (1995). Patients' perceptions of magnetic resonance imaging. *Clinical Radiology, 50*(3), 137-143.

Markwell S. (2009). Health service development and planning. Retrieved from http://www.healthknowledge.org.uk/public-health-textbook/organisation-management/5d-theory-process-strategy-development/health-service-development-planning

Masud, T., Blundell, A., Gordon, A. L., Mulpeter, K., Roller, R., Singler, K., Goeldlin, A., & Stuck, A. (2014). European undergraduate curriculum in geriatric medicine developed using an international modified Delphi technique. *Age and ageing, 43*(5), 695-702.

Matell, M. S., & Jacoby, J. (1972). Is there an optimal number of alternatives for Likert-scale items? Effects of testing time and scale properties. *Journal of Applied Psychology, 56*(6), 506.

McCall, I. W. (2002). *Benchmarking radiological services in Europe*. Retrieved from http://www.earonline.org/download/Benchmarking_radiological_services_in_Europe.pdf

McClelland, D. C. (1973). Testing for competence rather than intelligence. *American Psychologist, 28*(1), 1-14.

McMullan, M., Endacott, R., Gray, M. A., Jasper, M., Miller, C. M. L., Scholes, J., & Webb, C. (2003). Portfolios and assessment of competence: a review of the literature. *Journal of Advanced Nursing, 41*(3), 283-294.

McRobbie, D. W. (2007). *MRI from Picture to Proton*: Cambridge University Press.

Medical Radiation Practice Board of Australia. (2013). Professional capabilities for medical radiation practice. Retrieved from http://www.medicalradiationpracticeboard.gov.au/documents/default.aspx?record=WD13%2f12534&dbid=AP&chksum=OIuB81d6eQCqo%2bewP9PHOA%3d%3d

Midlöv, P., Höglund, P., Eriksson, T., Diehl, A., & Edgren, G. (2015). Developing a Competency-based Curriculum in Basic and Clinical Pharmacology–A Delphi Study among Physicians. *Basic & clinical pharmacology & toxicology, 117*(6), 413-420.

Miller, L., Price, R., & Vosper, M. (2011). Training and development for radiographers' extended roles: a case of ad hoc implementation. *Health Serv Manage Res, 24*(2), 60-68.

Ministry for Justice Culture and Local Government. (2003). *Health Care Professions Act CAP 464*. Valletta, Malta Retrieved from http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=8930&l=1.

Moberg, K. (2013). *Magneettikuvantamisessa Tyoskentelevien Rontgenhoita-Jien Koulutuksen Kehittaminen Heidan Nakokulmastaan (MRI radiographers Educations Development in view of radiographers).* (Post Graduate thesis), University of Oulu, Finland.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The, P. G. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med, 6*(7), 1-6.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic reviews, 4*(1), 1.

Momeni, P., Jirwe, M., & Emami, A. (2008). Enabling nursing students to become culturally competent–a documentary analysis of curricula in all Swedish nursing programs. *Scandinavian Journal of Caring Sciences, 22*(4), 499-506.

Morrow, S. L. (2005). Quality and trustworthiness in qualitative research in counseling psychology. *Journal of counseling psychology, 52*(2), 250.

Morse, J. M. (1994). Developing QHR. *Qualitative Health Research, 4*(4), 347-348.

Morten, K. A., & Peter, A. (2014). *Service Management 3.0 - the next generation of service*. Retrieved from ISS world services: http://www.publications.issworld.com/ISS/External/issworld/White_papers/Service_Management_30/

Mulder, M. (2001). Competence development - some background thoughts. *The Journal of Agricultural Education and Extension, 7*(4), 147 - 158.

Murphy, M. S., & Pushor, D. (2010). Encyclopedia of Curriculum Studies. Thousand Oaks, California: SAGE Publications, Inc. Retrieved from http://sk.sagepub.com/reference/curriculumstudies.

Muscat, N. A. (1999). Health care systems in transition: Malta. *WHO Regional Office for Europe, Copenhagen*.

Nancarrow, S. A., Booth, A., Ariss, S., Smith, T., Enderby, P., & Roots, A. (2013). Ten principles of good interdisciplinary team work. *Human resources for Health, 11*(1), 19.

Nelson, C. W., & Niederberger, J. (1989). Patient satisfaction surveys: an opportunity for total quality improvement. *Hospital & health services administration, 35*(3), 409-427.

New Zealand Medical Radiation Technologists Board. (2013a, October, 2013). Competencies Required for the Practice of: MAGNETIC RESONANCE IMAGING

New Zealand Medical Radiation Technologists Board. (2013b). Notice Replacing Prescribed Scope of Practice and Related Qualifications. Retrieved from http://www.mrtboard.org.nz/assets_mrtb/Uploads/MRT-SOP-and-Quals-notice-31.07.3.pdf

New Zealand Medical Radiation Technologists Board. (2016). Competence Standards for Medical Imaging and Radiation Therapy Practice in New Zealand. Retrieved from http://www.mrtboard.org.nz/assets_mrtb/Uploads/Competencies-Standards-and-Guidelines-Mar2019.pdf

New Zealand Medical Radiation Technologists Board. (2017). Consultation Outcomes: Revised Competencies for the Practice of Medical Imaging and Radiotherapy. Retrieved from http://www.mrtboard.org.nz/assets_mrtb/Uploads/Consultation-Outcomes-Mar2018.pdf

Newsome, R., Reddington, M., Breakwell, L., Chiverton, N., Cole, A., & Michael, A. (2012). Measuring competencies within the orthopaedic spinal service; MRI requesting rights by spinal extended scope physiotherapists within secondary care one year on. *Journal of Bone & Joint Surgery, British Volume, 94*(SUPP XXVI), 84-84.

Nova Scotia Association of Medical Radiation Technologists. (2015). College Information Retrieved from http://nsamrt.ca/act/index2.html

Novak, J. D., & Cañas, A. J. (2008a). *The theory underlying concept maps and how to construct and use them*. Retrieved from Florida Institute for Human and Machine Cognition Pensacola Fl, : http://eprint.ihmc.us/5/2/TheoryUnderlyingConceptMaps.pdf

Novak, J. D., & Cañas, A. J. (2008b). The theory underlying concept maps and how to construct and use them. *Florida Institute for Human and Machine Cognition Pensacola Fl, www. ihmc. us.[http://cmap. ihmc. us/Publications/ResearchPapers/T heoryCmaps/TheoryUnderlyingConceptMaps. htm]*.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*: Cambridge University Press.

O'Neill, G. (2010). Initiating curriculum revision: exploring the practices of educational developers. *International Journal for Academic Development, 15*(1), 61-71.

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: an example, design considerations and applications. *Information & Management, 42*(1), 15-29.

Olsen, D. (2012). SP-0615 The status of radiation protection training in Europe - the MEDRAPET survey. *Radiotherapy and Oncology, 103*, S241.

Opoku, S., Sarblah, S. R., & Antwi, W. (2013). *Assessment of Safety Standards of Magnetic Resonance Imaging at the Korle Bu Teaching Hospital (KBTH) in Accra, Ghana*: INTECH Open Access Publisher.

Ornstein, A. C., & Hunkin, F. (2004). *Curriculum foundations, principles and issues*: New York, NY: Allyn.

Ornstein, A. C., & Hunkin, F. (2009). *Curriculum Foundations, principles and issues* (5th ed.): Boston, Allyn and Bacon.

Pallan, M. J., Linnane, J. G., & Ramaiah, S. (2005). Evaluation of an independent, radiographer-led community diagnostic ultrasound service provided to general practitioners. *Journal of Public Health, 27*(2), 176-181.

Parsian, N., & Am, T. D. (2009). Developing and validating a questionnaire to measure spirituality: a psychometric process. *Global journal of health science, 1*(1), 2.

Patton, M. Q. (2001). *Qualitative research & evaluation methods*: Sage Publications, Incorporated.

Picano, E. (2004). Sustainability of medical imaging. *BMJ: British Medical Journal, 328*(7439), 578.

Piper, K., Buscall, K., & Thomas, N. (2010). MRI reporting by radiographers: Findings of an accredited postgraduate programme. *Radiography, 16*(2), 136-142.

Piper, K. J., & Buscall, K. L. (2008). MRI reporting by radiographers: The construction of an objective structured examination. *Radiography, 14*(2), 78-89.

Ponsignon, F., Smart, P., & Maull, R. (2011). Service delivery system design: characteristics and contingencies. *International Journal of Operations & Production Management, 31*(3), 324-349.

Portanier Mifsud, C., Castillo, J., & Portelli, J. L. (2014). Radiography students' clinical placement experiences in MRI: A phenomenological study. *Radiography, 21*(1), e17-e20.

Posner George, J. (2004). Analyzing the Curriculum: New York: McGraw-Hill, Inc.

Potter, M., Gordon, S., & Hamer, P. (2004). The Nominal Group Technique: A useful consensus methodology in physiotherapy research. *New Zealand Journal of Physiotherapy, 32*(3), 126-130.

Powell, C. (2003). The Delphi technique: myths and realities. *Journal of Advanced Nursing, 41*(4), 376-382.

Price, R. (2006). *Developing practice in radiography and diagnostic imaging.* (PhD thesis), University of Hertfordshire UK.

Prøitz, T. S., Havnes, A., Briggs, M., & Scott, I. (2017). Learning outcomes in professional contexts in higher education. *European Journal of Education, 52*(1), 31-43.

Prota, F., Rosano, A., San Martini, E., Cau, N., & Guasticchi, G. (2012). Appropriateness of Magnetic resonance imaging referrals in Latium (Italy)]. *Igiene e sanità pubblica, 68*(3), 411 - 420.

QSR International. (2013). NVIVO10. Retrieved from http://www.qsrinternational.com/products_nvivo.aspx

Rayens, M. K., & Hahn, E. J. (2000). Building consensus using the policy Delphi method. *Policy, politics, & nursing practice, 1*(4), 308-315.

Remedios, D., Hierath, M., Ashford, N., Bezzi, M., Cavanagh, P., Chateil, J.-F., Grenier, P., Simeonov, G., & Vilgrain, V. (2014). Imaging referral guidelines in Europe: now and in the future—EC Referral Guidelines Workshop Proceedings. *Insights into Imaging, 5*(1), 9-13.

Ribeiro, A., Nunes, A., & Gois, C. (2010). *Characterization of the Radiological Technician's Knowledge about Safe MR Practices [unpublished work]*. 3rd Euro-Med Congress for Radiographers. Retrieved from http://www.e-mcr.org/emcr/program.html

Rocka, T. D., & Morrish, D. G. (2010). Public School Administrators' Ratings of the Biological and Physical Science Competencies Needed By Beginning Agricultural Science Instructors. *Director, 1*, 2.

Rosenthal, D. I., Weilburg, J. B., Schultz, T., Miller, J. C., Nixon, V., Dreyer, K. J., & Thrall, J. H. (2006). Radiology order entry with decision support: initial clinical experience. *Journal of the American College of Radiology, 3*(10), 799-806.

Rothwell, W. J., & Lindholm, J. E. (1999). Competency identification, modelling and assessment in the USA. *International journal of training and development, 3*(2), 90-105.

Rowe, M., Frantz, J., & Bozalek, V. (2013). Beyond knowledge and skills: the use of a Delphi study to develop a technology-mediated teaching strategy. *BMC Medical Education, 13*(1), 51.

Sackman, H. (1975). *Delphi critique: Expert opinion, forecasting, and group process*. New York: Lexington Books.

Satava, R. M., & Gallagher, A. G. (2015). Next generation of procedural skills curriculum development: Proficiency-based progression. *Journal of Health Specialties, 3*(4), 198.

Saunders, D. E., Thompson, C., Gunny, R., Jones, R., Cox, T., & Chong, W. K. (2007). Magnetic resonance imaging protocols for paediatric neuroradiology. *Pediatric Radiology, 37*(8), 789-797.

Schmitt, F., Grosu, D., Mohr, C., Purdy, D., Salem, K., Scott, K., & Stoeckel, B. (2004). 3 Tesla MRI: successful results with higher field strengths. *Der Radiologe, 44*(1), 31-47.

Scott, J. (2014). *A matter of record: Documentary sources in social research*: John Wiley & Sons.

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*: John Wiley & Sons.

Seo, J., MacEntee, M., & Brondani, M. (2015). The use of Subject Matter Experts in Validating an Oral Health-Related Quality of Life measure in Korean. *Health and Quality of Life Outcomes, 13*, 138.

Shaikh, M. Z. A. (2013). *Validating Teachers' Competence for Personal Learning Environments: A Delphi Study*. Paper presented at the 3rd International Conference for e-learning and Distance Education, Riyadh.

Shannak, O., Dahabreh, Z., Gonsalves, S., Philipson, M., & Calder, S. (2010). The efficacy of a physiotherapy led acute knee injury clinic at Leeds General Infirmary. *Journal of Bone & Joint Surgery, British Volume, 92*(SUPP III), 423-423.

Shaw, S., Elston, J., & Abbott, S. (2004). Comparative analysis of health policy implementation. *Policy Studies, 25*(4), 259-266.

Shellock, F. G., & Spinazzi, A. (2008a). MRI safety update 2008: part 1, MRI contrast agents and nephrogenic systemic fibrosis. *American Journal of Roentgenology, 191*(4), 1129-1139.

Shellock, F. G., & Spinazzi, A. (2008b). MRI safety update 2008: part 2, screening patients for MRI. *American Journal of Roentgenology, 191*(4), 1140-1149.

Shumway, J. M., & Harden, R. M. (2003). AMEE Guide No. 25: The assessment of learning outcomes for the competent and reflective physician. *Medical teacher, 25*(6), 569-584.

Silva, A. K. A., Silva, E. L., Egito, E. S. T., & Carriço, A. S. (2006). Safety concerns related to magnetic field exposure. *Radiation and environmental biophysics, 45*(4), 245-252.

Simpson, G. C., Forbes, K., Teasdale, E., Tyagi, A., & Santosh, C. (2010). Impact of GP direct-access computerised tomography for the investigation of chronic daily headache. *The British Journal of General Practice, 60*(581), 897 - 901.

Singh, H., Arora, H. S., Vij, M. S., Rao, R., Khan, M. M., & Petersen, L. A. (2007). Communication outcomes of critical imaging results in a computerized notification system. *Journal of the American Medical Informatics Association, 14*(4), 459-466.

Sjögren, T., von Hedenberg, L., Parikka, E., Valkeinen, H., Heikkinen, A., & Piirainen, A. (2016). The core competences of Finnish physiotherapists in the light of research data. *Physiotherapy, 102*, e28-e29.

Skills for Health. (2007). CHS107 Acquire Magnetic Resonance Images for Diagnostic Purposes. Retrieved from https://tools.skillsforhealth.org.uk/competence/show?code=CHS107

Skills for Health. (2009). Strategic Plan 2010-15. Retrieved from http://www.skillsforhealth.org.uk/~/media/Resource-Library/PDF/Strategic%20Plan%202010-15%20Mar%202010.ashx

Smesny, T., & Bellah, K. A. (2012). Best practices for teaching equine reproduction in an online learning environment: A delphi study. *NACTA Journal, 56*(3), 34 - 41.

Smith, T. N., & Baird, M. (2007). Radiographers' role in radiological reporting: a model to support future demand. *Medical Journal of Australia, 186*(12), 629-631.

Stagnitti, K., Schoo, A., Reid, C., & Dunbar, J. (2005). Access and attitude of rural allied health professionals to CPD and training. *International Journal of Therapy and Rehabilitation, 12*(8), 355-362.

Stalmeijer, R. E., McNaughton, N., & Van Mook, W. N. (2014). Using focus groups in medical education research: AMEE Guide No. 91. *Medical teacher, 36*(11), 923-939.

Stemler, S. (2001). An overview of content analysis. *Practical assessment, research & evaluation, 7*(17), 137-146.

Stenhouse, L. (1975). *An introduction to curriculum research and development* (Vol. 46): Heinemann London.

Steward, B. (2001). Using nominal group technique to explore competence in occupational therapy and physiotherapy students during first-year placements. *The British Journal of Occupational Therapy, 64*(6), 298-304.

Streiner, D. L., Norman, G. R., & Cairney, J. (2015). *Health measurement scales: a practical guide to their development and use*: Oxford University Press, USA.

Strugnell, W. (2006). MRI Education and Certification Forum, Australia and New Zealand. *15th SMRT Annual Meeting.* Retrieved from http://cds.ismrm.org/protected/Presentations06E/S025

Sultana, R. (2009). Competence and competence frameworks in career guidance: complex and contested concepts. *International Journal for Educational and Vocational Guidance, 9*(1), 15-30.

Tanimoto, A., Nakashima, J., Kohno, H., Shinmoto, H., & Kuribayashi, S. (2007). Prostate cancer screening: The clinical value of diffusion-weighted imaging and dynamic MR imaging in combination with T2-weighted imaging. *Journal of magnetic resonance imaging, 25*(1), 146-152.

Taylor, R. M., Feltbower, R. G., Aslam, N., Raine, R., Whelan, J. S., & Gibson, F. (2016). Modified international e-Delphi survey to define healthcare professional competencies for working with teenagers and young adults with cancer. *BMJ open, 6*(5), 1-11.

The European Centre for the Development of Vocational Training. (2014). Terminology of European education and training. In James J Calleja (Ed.), (Second Edition ed.). Luxembourg: Publications office of the European Union.

The Society of Radiographers. (2013). Education and Career Framework for the Radiography Workforce. Retrieved from http://www.sor.org/learning/document-library/education-and-career-framework-radiography-workforce

The Society of Radiographers. (2016). Approval and Accreditation Board. Retrieved from http://sor.org/learning/education-accreditation/approval-and-accreditation-board

Thomas, P. A., Kern, D. E., Hughes, M. T., & Chen, B. Y. (2015). *Curriculum Development for Medical Education: A Six-Step Approach*: JHU Press.

Tombleson, P., Fox, R. A., & Dacre, J. A. (2000). Defining the content for the objective structured clinical examination component of the professional and linguistic assessments board examination: development of a blueprint. *Medical Education, 34*(7), 566-572.

Tomlinson, P., Hewitt, S., & Blackshaw, N. (2013). Joining up health and planning: how Joint Strategic Needs Assessment (JSNA) can inform health and wellbeing strategies and spatial planning. *Perspectives in public health, 133*(5), 254-262.

Törnqvist, E., Månsson, Å., Larsson, E. M., & Hallström, I. (2006). It's like being in another world–patients' lived experience of magnetic resonance imaging. *Journal of Clinical Nursing, 15*(8), 954-961.

Tse, A. M., Iwaishi, L. K., King, C. A., & Harrigan, R. C. (2006). A collaborative approach to developing a validated competence-based curriculum for health professions students. *Education for Health, 19*(3), 331-344.

Tyler, R. W. (1949). *Basic principles of curriculum and instruction*: University of Chicago press.

Vaartio-Rajalin, H., & Leino-Kilpi, H. (2011). Nurses as Patient Advocates in Oncology Care. *Clinical journal of oncology nursing, 15*(5), 526-532.

Vanhaecht, K., Panella, M., Van Zelm, R., & Sermeus, W. (2010). An overview on the history and concept of care pathways as complex interventions. *International Journal of Care Pathways, 14*(3), 117-123.

Vanhaecht, K., Witte, K. d., Depreitere, R., & Sermeus, W. (2006). Clinical pathway audit tools: a systematic review. *Journal of Nursing Management, 14*(7), 529-537.

Vazirani, N. (2010). Competencies and competency model-a brief overview of its development and application. *SIES Journal of management, 7*(1), 121 - 131.

von der Gracht, H. A. (2008). *The future of logistics: Scenarios for 2025*: Springer Science & Business Media.

von der Gracht, H. A. (2012). Consensus measurement in Delphi studies: review and implications for future quality assurance. *Technological Forecasting and Social Change, 79*(8), 1525-1536.

von Korff, M., & Goldberg, D. (2001). Improving outcomes in depression: the whole process of care needs to be enhanced. *British Medical Journal, 323*(7319), 948 - 949.

Wainwright, D., Boichat, C., & McCracken, L. M. (2013). Using the nominal group technique to engage people with chronic pain in health service development. *The International journal of health planning and management, 29*(1), 52-69.

Wallengren, J. (2011). Identification of core competencies for primary care of allergy patients using a modified Delphi technique. *BMC medical education, 11*(1), 12.

Ware, G. W. (2003). Patient satisfaction surveys. *OPTOMETRY-ST LOUIS-, 74*(10), 671-672.

Weigel, T., Mulder, M., & Collins, K. (2007). The concept of competence in the development of vocational education and training in selected EU member states. *Journal of Vocational Education & Training, 59*(1), 53-66.

Wennberg, J., & Gittelsohn, A. (1973). Small Area Variations in Health Care Delivery A population-based health information system can guide planning and regulatory decision-making. *Science, 182*(4117), 1102-1108.

Wennberg, J. E. (2002). Unwarranted variations in healthcare delivery: implications for academic medical centres. *BMJ: British Medical Journal, 325*(7370), 961 - 964.

Westbrook, C. (2017). Opening the debate on MRI practitioner education–Is there a need for change? *Radiography, 23*(Supplement 1), S70 - S74.

Westbrook, C., & Talbot, J. (2009). What do MRI radiographers really know? *European Journal of Radiography, 1*(2), 52-60.

Wheeldon, J., & Faubert, J. (2009). Framing experience: Concept maps, mind maps, and data collection in qualitative research. *International Journal of Qualitative Methods, 8*(3), 68-83.

White, R. W. (1959). Motivation reconsidered - the concept of competece. *Psychological Review, 66*(5), 297-333.

Wong, A. K. (2006). Curriculum development in anesthesia: basic theoretical principles. *Canadian Journal of Anesthesia, 53*(9), 950-960.

Woodard, P. K., Bluemke, D. A., Cascade, P. N., Finn, J. P., Stillman, A. E., Higgins, C. B., White, R. D., & Yucel, E. K. (2006). ACR practice guideline for the performance and interpretation of cardiac magnetic resonance imaging (MRI). *J Am Coll Radiol, 3*(9), 665-676.

Woodruffe, C. (1993). What Is Meant by a Competency? *Leadership & Organization Development Journal, 14*(1), 29-36.

Woodward, P. (2000). *MRI for Technologists*: The McGraw-Hill Companies.

World Health Organization. (2006). *Quality of care: a process for making strategic choices in health systems*. Geneva: World Health Organization.

Yanow, D., & Schwartz-Shea, P. (2015). *Interpretation and method: Empirical research methods and the interpretive turn*: Routledge.

Yazdanparast, A., Manuj, I., & Swartz, S. M. (2010). Co-creating logistics value: a service-dominant logic perspective. *International Journal of Logistics Management, The, 21*(3), 375-403.

Yielder, J. (2001). *Professional expertise: A model for integration and change.* (PhD thesis), University of Auckland, New Zealand.

Young, A. J. (2008). *An investigation into formal role extension opportunities for MRI technologists in New Zealand.* (master's thesis), UNITEC, New Zealand.

Appendix A - Participant information sheets and informed consent sheets

Letter Seeking Permission from Institutions (public and private)

Research Project Title: ‘Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta’.

Objective 1: To develop a Service Portfolio for MRI services in Malta

Name of Researcher: Joseph Castillo
Address of researcher: 133, Lobelia, St.Michael Street, Fgura, FGR1029
Contact number of researcher: 21667656, 99437290

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

Dear _________

I am a PhD student at the University of Malta conducting a research study the purpose of which is to develop an inventory of biomedical imaging physics learning outcomes which is specific to the MRI service needs and particular milieu of a network of radiographer-managed MRI units in Malta. The potential benefits of this study are:

(a) for local healthcare services: since MRI physics learning outcomes are fundamental for image quality and patient / occupational safety the results of this study would improve the quality and outcomes of MRI exam to the satisfaction of the patient as an external customer and the referrer as an internal customer.

(b) for the radiography profession in Malta: to provide an inventory of biomedical imaging physics learning outcomes which would be used to develop the role of the radiographer in Malta.

The first objective of the study would be to develop an MRI service portfolio through a series of interviews with representatives of the key stakeholders. The opinions of the participants would be used to generate statements for a Delphi process leading towards the development of a consensus document concerning MRI services in Malta with the same participants.

I am requesting permission to conduct the study at the Hospital. I have sought and gained permission from Dr Salvina Zrinzo, Dr Lina Janulova, Ms Charmaine Attard and Ms Margaret Muscat (Manager Physiotherapy Services) to interview a number of participants regarding issues related to the MRI service.

All information will be kept strictly confidential and participants will remain anonymous throughout the study and publication of results. All participants will be given a letter of explanation and asked to sign a consent form. Participants will be advised that they have the right to withdraw from the study at any time and their data will not be included in the study

Approval will be requested by the University of Malta Ethics and Research Committee.
Whilst thanking you in advance I await your reply,

Joseph Castillo	Date	Signature
Prof Carmel J Caruana	Date	Signature

I give my consent for the following persons to participate in this study:

Name Surname	Date	Signature

Consent Form for Interview and Delphi

Research Project Title: ‘Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta’

Research: Objective 1 – Developing an MRI service portfolio

Researcher: Joseph Castillo, Manager Medical Imaging Services, Mater Dei Hospital Malta

Contact details: Phone: 99437290, email: joseph.castillo@gov.mt

I, (full name), ________________________________ give my consent to participate in the research study.

I understand that:

1. My participation is voluntary.

2. I will be asked to give opinions on issues related to the research and that these opinions will not result in any judgement of me. The researcher has explained to my satisfaction the purpose, procedures and possible risks involved.

3. I have the right to withdraw at any time without consequence. I agree that should I withdraw from the study, the data collected up to that point may be used by the researcher for the purposes described in the information sheet.

4. I may be asked to provide written justification for my response for purposes of clarity.

5. I will be kept informed of the results of each round of the questionnaire.

6. Anonymity amongst panel members is assured.

7. Confidentiality of all data gathered will be maintained during the analysis of the research.

8. The Delphi will be through the use of web-based questionnaire and again all data will be destroyed once the project is finished.

9. I will respect the confidentiality of the Delphi by not divulging anything that was discussed during the sessions outside the sessions.

10. I give permission to allow the researcher to anonymously quote what I have communicated to him in written or spoken presentations or publications.

________________	________________	____________
Name of Participant	Date	Signature
________________	________________	____________
Joseph Castillo	Date	Signature
________________	________________	____________
Prof Carmel Caruana	Date	Signature

Participants Information Sheet

Objective 1 – Developing an MRI service portfolio for Malta

08th April, 2013

Invitation to participate in a research study towards a Doctor of Philosophy

I am a PhD student at the University of Malta conducting a study titled 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

You are being invited to take part in this research study because as consultant radiologist / team leader / nurse / physician / vendor / physiotherapist you are considered an MRI stakeholder. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Purpose of the Study

The end purpose of this study is to develop an inventory of biomedical imaging physics learning outcomes which is specific to local MRI needs and to the particular milieu of a network of radiographer-managed MRI units in Malta. The potential benefits of this study are:

1. For local health policy: The results of this study would improve the quality and outcome of the MRI exam to the satisfaction of the patient as an external customer and the referrer as an internal customer. This would certainly enhance the effectiveness of the medical imaging department as an organization.
2. For the local radiography profession: To the best of my knowledge, this study will be the first systematic and comprehensive study of MRI competence profile based on expertise and European framework. The study has implications for the development of a local MRI competence profile, mandatory registration and CPD.

First objective of the study

The first objective of the study is to develop an MRI service portfolio through an interview followed by a Delphi process. Other MRI stakeholders will be invited to take part in this study. The opinions and perceptions of the participants during an interview study held between November 2012 and January 2013 were used to develop a number of statements. These statements will be used in a Delphi technique to achieve the best agreement possible on a 2020 vision MRI services portfolio for Malta.

Voluntary Participation

It is up to you to decide whether or not to take part. If you decide to take part please sign the consent form attached and return it to the researcher. If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw, or a decision not to take part will not affect you in any way.

Anonymity and confidentiality

There will be anonymity amongst panel members and the opinions of the panel will remain confidential throughout the study and when the results are made public. Participants will be coded with a number, known only by the researcher and no other person except the researcher will have access to the computer where all the data will be stored.

Complaints

If you have any complaints about the study or about any possible harm you might have suffered please feel free to contact my University supervisor Prof Carmel Caruana or head of the department Dr Paul Bezzina who will be able to answer any of your queries or complaints.

Ethical approval

Ethical approval from the University of Malta has been sought before conduction of this study.

Dissemination of results

The main purpose of the results of this study is to assist me as the researcher in obtaining a doctorate degree. Some of the results will be published in academic journals. There will be no identification either directly or indirectly of any participants involved in the study. If you wish you can obtain a copy of the published literature through the researcher.

Contacts for further Information

Research student: Joseph Castillo
Mater Dei Hospital, Malta
Email: joseph.castillo@gov.mt
Telephone: 21667656, 99437290

Research Supervisor: Prof Carmel J Caruana
Lecturer
Faculty of Health Sciences
University of Malta
Email: carmel.j.caruana@um.edu.mt
Telephone: 23401848

Head of Department: Dr Paul Bezzina
Faculty of Health Sciences
University of Malta
Email: paul.bezzina@um.edu.mt
Telephone:
You will be given a copy of the information sheet and a signed consent form to keep

Thank you in advance for participating in this study

Yours sincerely

Joseph Castillo

Letter Seeking Permission from Institutions

Research Project Title: 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

Objective 2: To develop and optimize an MRI care pathway in Malta

Name of Researcher: Joseph Castillo
Address of researcher: 133, Lobelia, St.Michael Street, Fgura, FGR1029
Contact number of researcher: 21667656, 99437290, 25456773

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

Dear Dr _______________

As you are aware from previous correspondence I am a PhD student at the University of Malta conducting a research study the purpose of which is to develop an inventory of biomedical imaging physics learning outcomes which is specific to MRI radiographer role development needs in Malta.

Following on from the first objective whereby a 2020 vision of the MRI service portfolio for Malta is being developed through consensus by a panel of MRI experts the focus now shifts to the development of internal processes and decisions that leads to operational excellence.

The second objective of this study is to develop and optimize a care pathway for MRI in Malta utilizing a nominal group technique with representatives from health care management.

I am requesting permission to invite a number of professionals in healthcare management to participate in this study. The study would involve one NGT session that is carried out during normal working hours. The NGT would focus on the service concept and the key activities necessary for better outcomes, reduced costs and shorter cycle times.

All information will be kept strictly confidential and participants will remain anonymous throughout the study and publication of results. All participants will be given a letter of explanation and asked to sign a consent form. Participants will be advised that they have the right to withdraw from the study at any time and their data will not be included in the study

Approval is required by the University of Malta Ethics and Research Committee.

Whilst thanking you in advance I await your reply,

__________________	_________________
Joseph Castillo	Date
__________________	_________________
Prof Carmel J Caruana	Date

I give my permission to invite members of the MHEC healthcare management practising in various institutions:

________________________	_________________
Name Surname	Date

Participants Information Sheet

Objective 2 – Developing an MRI care pathway for Malta

30th June 2013

Invitation to participate in a research study towards a Doctor of Philosophy

I am a PhD student at the University of Malta conducting a study titled 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

You are being invited to take part in this research study because as a healthcare professional in healthcare management you are considered an important stakeholder who either interact daily with or influence the development of MRI practice. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please feel free to ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Purpose of the Study

The end purpose of this study is to develop an inventory of biomedical imaging physics learning outcomes which is specific to local MRI needs and to the particular milieu of a network of radiographer-managed MRI units in Malta. The potential benefits of this study are:

(a) For local health policy: The results of this study would improve the quality and outcome of the MRI exam to the satisfaction of the patient as an external customer and the referrer as an internal customer. This would certainly enhance the effectiveness of the medical imaging department as an organization.

(b) For the local radiography profession: To the best of my knowledge, this study will be the first systematic and comprehensive study of MRI competence profile based on expertise and European framework. The study has implications for the development of a local MRI competence profile, mandatory registration and CPD.

First objective of the study

The first objective of the study was to develop an MRI service portfolio through an interview followed by a Delphi process. Other MRI stakeholders were invited to take part in this study. Their opinions and perceptions led to the development of a 2020 MRI service portfolio.

Second objective of the study – your participation

The second objective of the study is to develop an MRI care pathwat, the focus of which would centre about the service concept and key activities leading to better outcomes, reduced costs and shorter cycle times. A nominal group technique will be utilized to achieve this objective. The Nominal Group Technique (NGT), is a qualitative method of data collection, used to guide group meetings to arrive to a consensus on the identification of key problems, in the development of solutions or decision making.

The meeting venue and date will be communicated to you in the coming days. The NGT session is expected to last approx 2 hours.

Voluntary Participation

It is up to you to decide whether or not to take part. If you decide to take part please confirm your participation via a returned email. If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw, or a decision not to take part will not affect you in any way.

Confidentiality

The opinions of the panel will remain confidential throughout the main study and when the results are made public. Participants will be coded with a number, known only by the researcher and no other person except the researcher will have access to the computer where all the data will be stored.

Complaints

If you have any complaints about the study or about any possible harm you might have suffered please feel free to contact my University supervisor Dr Carmel Caruana or head of the department Dr Paul Bezzina who will be able to answer any of your queries or complaints.

Ethical approval

Ethical approval from the University of Malta has been sought before conduction of this study.

Dissemination of results

The main purpose of the results of this study is to assist me as the researcher in obtaining a doctorate degree. Some of the results will be published in academic journals. There will be no identification either directly or indirectly of any participants involved in the study. If you wish you can obtain a copy of the published literature through the researcher.

Contacts for further Information

Research student: Joseph Castillo
Mater Dei Hospital, Malta
Email: joseph.castillo@gov.mt
Telephone: 21667656, 99437290

Research Supervisor: Prof Carmel J Caruana
Lecturer
Faculty of Health Sciences
University of Malta
Email: carmel.j.caruana@um.edu.mt
Telephone: 23401848

Head of Department: Dr Paul Bezzina
Faculty of Health Sciences
University of Malta
Email: paul.bezzina@um.edu.mt
Telephone:
You will be given a copy of the information sheet and a signed consent form to keep

Thank you in advance for participating in this study

Yours sincerely

Joseph Castillo

Consent Form for NGT – Objective 2

Research Project Title: 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

Objective 2: To develop and optimize an MRI care pathway.

Researcher: Joseph Castillo, Manager Medical Imaging Services, Mater Dei Hospital Malta

Contact details: Phone: 99437290, email: joseph.castillo@gov.mt

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

I, (full name), ________________________________ give my consent to participate in the research study.

I understand that:

1. My participation is voluntary.

2. I will be asked to give opinions on issues related to the research and that these opinions will not result in any judgement of me. The researcher has explained to my satisfaction the purpose, procedures and possible risks involved.

3. I have the right to withdraw at any time without consequence. I agree that should I withdraw from the study, the data collected up to that point may be used by the researcher for the purposes described in the information sheet.

4. I may be asked to provide clarifications for my responses.

5. Confidentiality of all data gathered will be maintained during the analysis and publication of the research.

6. The session will be audio-recorded and I have been assured that these recordings will be destroyed once the project is finished.

7. I give permission to allow the researcher to anonymously quote what I have communicated to him in written or spoken presentations or publications.

________________	________________	____________
Name of Participant	Date	Signature
________________	________________	____________
Joseph Castillo	Date	Signature
________________	________________	____________
Prof Carmel J Caruana	Date	Signature

Letter Seeking Permission from Institutions

Research Project Title: ‘Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta’.

Name of Researcher: Joseph Castillo
Address of researcher: 133, Lobelia, St.Michael Street, Fgura, FGR1029
Contact number of researcher: 21667656, 99437290, 25456773

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

Mr Ben Kennedy
SMRT President

Dear Mr Kennedy

I am a PhD student at the University of Malta conducting a research study the purpose of which is to develop an inventory of biomedical imaging physics learning outcomes which is specific to MRI radiographer role development needs in Malta.

Following on from the first and second objective whereby a 2020 vision of the MRI service portfolio and service management model for Malta are being developed through consensus by a panel of MRI experts the focus now shifts on the competence profiles for MRI radiographers.

I am requesting permission to use the SMRT list serve in order to ask questions about competence profiles.

All information will be kept strictly confidential and participants will remain anonymous throughout the study and publication of results. All participants will be informed about the study and will be advised that they have the right to withdraw from the study at any time and their data will not be included in the study

Approval is required by the University of Malta Ethics and Research Committee.

Whilst thanking you in advance I await your reply,

__________________ __________________
Joseph Castillo Date

I give my permission to use the list serve for the purpose of the study:

________________________ __________________
Ben Kennedy Date

From: Joseph Castillo [josecast@melita.com]
Sent: 25 June 2013 19:21
To: Castillo Joseph at MDH
Subject: Fwd: Re: PhD letter of permission

-------- Original Message --------
Subject: Re: PhD letter of permission
Date: Tue, 25 Jun 2013 11:10:17 +0000
From: Ben Kennedy <Ben.Kennedy@qscan.com.au>
To: Joseph Castillo <josecast@melita.com>

```
Hi Jo
You have a green light. Just use a link on your email to redirect
interested participants.

Cheers
Ben

On 18/06/2013, at 4:53 AM, "Joseph Castillo" <josecast@melita.com>
wrote:

> Hi Ben,
>
> Hope you are well.  I am doing a PhD project and would like to use
the list serve to ask for some clarification on MRI competences. The
respondent's confidentiality will be guaranteed.
>
> Thanks for your support
>
> Joe Castillo
> Malta
> <Letter seeking permission from institutions for list serve Ben
Kennedy.docx>
```

Participants Information Sheet

Objective 3 – Comparative analysis of existing competence profiles, qualifications, certification frameworks for MRI radiographers in the major English-speaking countries

30th June 2013

Invitation to participate in a research study towards a Doctor of Philosophy

I am PhD student at the University of Malta conducting a study titled 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

You are being invited to take part in this research study because as a healthcare professional in healthcare management you are considered an important stakeholder who either interact daily with or influence the development of MRI practice. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please feel free to ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Purpose of the Study

The end purpose of this study is to develop an inventory of biomedical imaging physics learning outcomes which is specific to local MRI needs and to the particular milieu of a network of radiographer-managed MRI units in Malta. The potential benefits of this study are:

For local health policy: The results of this study would improve the quality and outcome of the MRI exam to the satisfaction of the patient as an external customer and the referrer as an internal customer. This would certainly enhance the effectiveness of the medical imaging department as an organization.

For the local radiography profession: To the best of my knowledge, this study will be the first systematic and comprehensive study of MRI competence profile based on expertise and European framework. The study has implications for the development of a local MRI competence profile, mandatory registration and CPD.

Third objective of the study – your participation

The third objective of the study is to do a comparative study of existing competence profiles, qualifications and certification frameworks for MRI radiographers in the major English speaking countries. Your participation in this study is to answer questions in order to clarify certain aspects that are unavailable in the public domains such as the context in which the above are being used, how they were developed and what changes are expected in the future.

Voluntary Participation

It is up to you to decide whether or not to take part.

If you decide to take part please confirm your participation via a returned email. If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw, or a decision not to take part will not affect you in any way.

Confidentiality

The opinions of the panel will remain confidential throughout the main study and when the results are made public. Participants will be coded with a number, known only by the researcher and no other person except the researcher will have access to the computer where all the data will be stored.

Complaints

If you have any complaints about the study or about any possible harm you might have suffered please feel free to contact my University supervisor Prof Carmel Caruana or head of the department Dr Paul Bezzina who will be able to answer any of your queries or complaints.

Ethical approval

Ethical approval from the University of Malta has been sought before conduction of this study.

Dissemination of results

The main purpose of the results of this study is to assist me as the researcher in obtaining a doctorate degree. Some of the results will be published in academic journals. There will be no identification either directly or indirectly of any participants involved in the study. If you wish you can obtain a copy of the published literature through the researcher.

Contacts for further Information

Research student: Joseph Castillo
Mater Dei Hospital, Malta
Email: joseph.castillo@gov.mt
Telephone: 21667656, 99437290

Research Supervisor: Prof Carmel J Caruana
Lecturer
Faculty of Health Sciences
University of Malta
Email: carmel.j.caruana@um.edu.mt
Telephone: 23401848

Head of Department: Dr Paul Bezzina
Faculty of Health Sciences
University of Malta
Email: paul.bezzina@um.edu.mt
Telephone:
You will be given a copy of the information sheet and a signed consent form to keep

Thank you in advance for participating in this study

Yours sincerely

Joseph Castillo

Survey cover letter

Dear participant,

The aim of this web based questionnaire is to investigate the present state of MRI education in English speaking countries across the world. This questionnaire should only take about 30 minutes to complete.

Benefits of the study:

You will be contributing to the development of a competence profile and learning outcomes for MRI radiographers in Malta.

Confidentiality:

Your responses will be kept completely confidential. You will be assigned a participant number and only the participant number will appear in the dissertation. Only the researcher will see your individual survey responses. The responses will be stored electronically in a password protected folder. No hard copies will be kept. Following data collection and publication of the results all data will be destroyed.

Right to withdraw at any time:

Your participation is voluntary. You are free to withdraw your participation from this study at any time without penalty. If you do not want to continue, you can simply leave this website.

If you do not click on the "submit" button at the end of the survey, your answers and participation will not be recorded.

Contact information:

If you have concerns or questions about this study, please contact Joseph Castillo at joseph.castillo@gov.mt or the PhD project supervisor Dr Carmel J Caruana at carmel.j.caruana@um.edu.mt.

Consent to participate:

By participating in the survey, we acknowledge that you have read this information and have consented to participate and contribute to this research.

If you wish a summary of the results please leave your email address in the space provided within the demographic section.

Thank you.

Joseph Castillo

Letter Seeking Permission from Institutions

Research Project Title: ‘Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta’.

Objective 4: To develop and validate a competence profile, qualification and certification framework for MRI radiographers in Malta

Name of Researcher: Joseph Castillo
Address of researcher: 133, Lobelia, St.Michael Street, Fgura, FGR1029
Contact number of researcher: 21667656, 99437290, 25456773

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

Dear Dr

Following on from the first three objectives whereby a 2020 vision of the MRI service portfolio for Malta, an MRI Clinical Care Pathway were developed and a comparative study of competence frameworks was carried out, the focus now shifts to the development and validation of a competence profile, qualification and certification frameworks for MRI Radiographers in Malta.

I am requesting permission to invite one of the lecturers within the Radiography Division to participate in this study. The study would involve filling up a number of Likert statements to validate the competence profile, qualification and certification frameworks. There may be the possibility that the participant will be interviewed to clarify issues raised during the survey.

All information will be kept strictly confidential and participant will remain anonymous throughout the study and publication of results. Participant will be given a letter of explanation and asked to sign a consent form. Participant will be advised that he has the right to withdraw from the study at any time and the data will not be included in the study

Approval is required by the University of Malta Ethics and Research Committee.

Whilst thanking you in advance I await your reply,

________________ ________________
Joseph Castillo Date

________________ ________________
Prof Carmel J Caruana Date

I give my permission to invite members of the Medical Imaging management.

____________________ ________________
Name Surname Date

Participants Information Sheet

Objective 4 – To develop and validate a competence profile, qualification and certification framework for MRI radiographers in Malta

Invitation to participate in a research study towards a Doctor of Philosophy

I am a PhD student at the University of Malta conducting a study titled 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

You are being invited to take part in this research study because as a healthcare professional in healthcare management you are considered an important stakeholder who either interact daily with or influence the development of MRI practice. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please feel free to ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Purpose of the Study

The end purpose of this study is to develop an inventory of biomedical imaging physics learning outcomes which is specific to local MRI needs and to the particular milieu of a network of radiographer-managed MRI units in Malta. The potential benefits of this study are:

For local health policy: The results of this study would improve the quality and outcome of the MRI exam to the satisfaction of the patient as an external customer and the referrer as an internal customer. This would certainly enhance the effectiveness of the medical imaging department as an organization.

For the local radiography profession: To the best of my knowledge, this study will be the first systematic and comprehensive study of MRI competence profile based on expertise and European framework. The study has implications for the development of a local MRI competence profile, mandatory registration and CPD.

Fourth objective of the study – your participation

The fourth objective of the study is to to develop and validate a competence profile, qualification and certification framework for MRI radiographers in Malta. The competence profile, and qualification / certification frameworks will be developed from data obtained in objectives 1, 2 and 3. Your participation in this study is to validate the competence profile and frameworks.

For your information objective 1 was to develop a 2020 vision of the MRI service portfolio for Malta; objective 2 was to develop a MRI care pathway for adults undergoing MRI in Malta and objective 3 was a comparative study of existing competence profiles, qualification / certification frameworks for MRI radiographers in the major English speaking countries and Europe.

Voluntary Participation

It is up to you to decide whether or not to take part.

If you decide to take part please confirm your participation via a returned email. If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw, or a decision not to take part will not affect you in any way.

Confidentiality

The opinions of the panel will remain confidential throughout the main study and when the results are made public. Participants will be coded with a number, known only by the researcher and no other person except the researcher will have access to the computer where all the data will be stored.

Complaints

If you have any complaints about the study or about any possible harm you might have suffered please feel free to contact my University supervisor Prof Carmel Caruana who will be able to answer any of your queries or complaints.

Ethical approval

Ethical approval from the University of Malta has been sought before conduction of this study.

Dissemination of results

The main purpose of the results of this study is to assist me as the researcher in obtaining a doctorate degree. Some of the results will be published in academic journals. There will be no identification either directly or indirectly of any participants involved in the study. If you wish you can obtain a copy of the published literature through the researcher.

Contacts for further Information

Research student: Joseph Castillo
Mater Dei Hospital, Malta
Email: joseph.castillo@gov.mt
Telephone: 21667656, 99437290

Research Supervisor: Prof Carmel J Caruana
Lecturer
Faculty of Health Sciences
University of Malta
Email: carmel.j.caruana@um.edu.mt
Telephone: 23401848

Thank you in advance for participating in this study

Yours sincerely

Joseph Castillo

Participant Information for objective 4 sent via email

Dear Participant,

I am a PhD student at the University of Malta conducting a study titled 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

The objective of this survey is to validate a competence profile for MRI radiographers in Malta. The competence profile, was developed from data obtained in objectives 1, 2 and 3. Your participation in this study is to validate the competence profile.

For your information in objective 1 an MRI service portfolio for Malta was developed; in objective 2 an MRI care pathway for adults undergoing MRI in Malta was optimized and in objective 3 a comparative study of existing competence profiles for MRI radiographers in the major English speaking countries was carried out in order to find elements of good practice.

This survey consists of a Competence Profile made up of 7 Key activities
https://www.surveymonkey.com/s/KMYPJYV

It should only take about 40 minutes to complete.

If you are using the attached hardcopy version please return the questionnaire to the researcher via email or at the following address:
Joseph Castillo
133, St.Michael Street
Fgura FGR1029
or contact me to arrange collection

Voluntary Participation

It is up to you to decide whether or not to take part.

If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw, or a decision not to take part will not affect you in any way.

Confidentiality

The opinions will remain confidential throughout the main study and when the results are made public. Participants will be coded with a number, known only by the researcher and no other person except the researcher will have access to the computer where all the data will be stored.

Complaints

If you have concerns or questions about this study, please contact Joseph Castillo at josecast@melita.com or the PhD project supervisor Prof Carmel J Caruana at carmel.j.caruana@um.edu.mt.

Ethical approval

Ethical approval from the University of Malta has been sought before conduction of this study.

Dissemination of results

The main purpose of the results of this study is to assist me as the researcher in obtaining a doctorate degree. Some of the results will be published in academic journals. There will be no identification either directly or indirectly of any participants involved in the study. If you wish you can obtain a copy of the published literature through the researcher.

Contacts for further Information

Research student: Joseph Castillo

Mater Dei Hospital, Malta
Email: joseph.castillo@gov.mt
Telephone: 21667656, 99437290

Research Supervisor: Prof Carmel J Caruana
Faculty of Health Sciences
University of Malta
Email: carmel.j.caruana@um.edu.mt
Telephone: 23401848
Thank you in advance for participating in this study
Yours sincerely

Joseph Castillo

Consent Form for participation – Objective 4

Research Project Title: 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

Objective 4: to validate a competence profile for MRI radiographers in Malta

Researcher: Joseph Castillo, Manager Medical Imaging Services, Mater Dei Hospital Malta

Contact details: Phone: 99437290, email: joseph.castillo@gov.mt; josecast@melita.com

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

I, (full name), ________________________________ give my consent to participate in the research study.

I understand that:

1. My participation is voluntary.

2. I will be asked to give opinions on issues related to the research and that these opinions will not result in any judgement of me. The researcher has explained to my satisfaction the purpose, procedures and possible risks involved.

3. I have the right to withdraw at any time without consequence. I agree that should I withdraw from the study, the data collected up to that point may be used by the researcher for the purposes described in the information sheet.

4. I may be asked to provide clarifications for my responses.

5. Confidentiality of all data gathered will be maintained during the analysis and publication of the research.

6. I give permission to allow the researcher to anonymously quote what I have communicated to him in written or spoken presentations or publications.

________________	________________	____________
Name of Participant	Date	Signature
________________	________________	____________
Joseph Castillo	Date	Signature
________________	________________	____________
Prof Carmel J Caruana	Date	Signature

Letter Seeking Permission from Institutions

Research Project Title: 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

Name of Researcher: Joseph Castillo
Address of researcher: 133, Lobelia, St.Michael Street, Fgura, FGR1029
Contact number of researcher: 21667656, 99437290, 25456773

Name of Supervisor: Prof Carmel J Caruana
Contact number of supervisor: 23401848

Dear

Following on from the first four objectives whereby a competence profile for MRI radiographers has been developed the focus now shifts on to the main objective of the PhD project - to develop and validate comprehensive inventory of biomedical imaging physics learning outcomes to support the certification of MRI radiographers in Malta.

I am requesting permission to invite medical physicists and radiologists to participate in the study. The study would involve answer a number of Likert statements to validate an inventory of biomedical imaging physics learning outcomes. There may be the possibility that the participant will be interviewed to clarify issues raised during the survey.

All information will be kept strictly confidential and participant will remain anonymous throughout the study and publication of results. Participant will be given a letter of explanation and asked to consent to participate. Participant will be advised that he/she has the right to withdraw from the study at any time and the data will not be included in the study

Approval is required by the University of Malta Ethics and Research Committee.

Whilst thanking you in advance I await your reply,

__________________ __________________
Joseph Castillo Date

__________________ __________________
Prof Carmel J Caruana Date

I give my permission to invite medical physicists and radiologists to participate in this study.

________________________ __________________
Name Surname Date

Participants Information Sheet

Objective 5 – To develop and validate an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta

Invitation to participate in a research study towards a Doctor of Philosophy

I am a PhD student at the University of Malta conducting a study titled 'Development of an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta'.

You are being invited to take part in this research study because as a healthcare professional involved in MRI you are considered an important stakeholder. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please feel free to ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Purpose of the Study

The end purpose of this study is to develop an inventory of biomedical imaging physics learning outcomes which is specific to local MRI needs and to the particular milieu of a network of radiographer-managed MRI units in Malta. The potential benefits of this study are:

For local health policy: The results of this study would improve the quality and outcome of the MRI exam to the satisfaction of the patient as an external customer and the referrer as an internal customer. This would certainly enhance the effectiveness of the medical imaging department as an organization.

For the local radiography profession: To the best of my knowledge, this study will be the first systematic and comprehensive inventory of biomedical imaging physics learning outcomes specific for Maltese MRI radiographers. The study has implications for the development of a certification process leading to a speciality in MRI radiography.

Fifth objective of the study – your participation

1. The fifth objective of the study is to to develop and validate an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta using a Delphi process. Your participation in this study is to validate the inventory of learning outcomes that would be necessary and sufficient to support the list of competences (competence profile) for MRI radiographers in Malta developed in a previous phase of the project .

The previous objectives of the project were as follows: objective 1 was to develop a 2020 vision of the MRI service portfolio for Malta; objective 2 was to develop a MRI care pathway for patients undergoing MRI in Malta, objective 3 was a comparative study of MRI qualification and certification frameworks amongst English-speaking countries and objective 4 was to develop and validate a competence profile (a list of competences) for MRI radiographers in Malta.

The Delphi process will be repeated until consensus is achieved. Delphi studies are often stopped when in interquartile range of 1.0 or less is attained on the greater majority of the statements. This cut off will also be used for this study.

Voluntary Participation

It is up to you to decide whether or not to take part.

If you decide to take part please confirm your participation via a returned email. If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw, or a decision not to take part will not affect you in any way.

Confidentiality

The opinions of the panel will remain confidential throughout the main study and when the results are made public. Participants will be coded with a number, known only by the researcher and no other person except the researcher will have access to the computer where all the data will be stored.

Complaints

If you have any complaints about the study or about any possible harm you might have suffered please feel free to contact my University supervisor Prof Carmel Caruana who will be able to answer any of your queries or complaints.

Ethical approval

Ethical approval from the University of Malta has been sought before conduction of this study.

Dissemination of results

The main purpose of the results of this study is to assist me as the researcher in obtaining a doctorate degree. Some of the results will be published in academic journals. There will be no identification either directly or indirectly of any participants involved in the study. If you wish you can obtain a copy of the published literature through the researcher.

Contacts for further Information

Research student: Joseph Castillo
Mater Dei Hospital, Malta
Email: joseph.castillo@gov.mt
Telephone: 21667656, 99437290

Research Supervisor: Prof. Carmel J Caruana
Department of Medical PhysicsFaculty of Health Sciences
University of Malta
Email: carmel.j.caruana@um.edu.mt
Telephone: 23401848

Thank you in advance for participating in this study

Yours sincerely

Joseph Castillo

Introduction to web questionnaire and consent

Dear participant,

The aim of this questionnaire is to validate MRI physics learning outcomes for MRI radiographers in Malta. This questionnaire should only take about 60 minutes to complete. Although desirable there is no need to complete the whole questionnaire in one session

Benefits of the study:

You will be contributing to the development of MRI Physics learning outcomes for MRI radiographers in Malta.

Confidentiality:

Your responses will be kept completely confidential. You will be assigned a participant number and only the participant number will appear in the dissertation. Only the researcher will see your individual survey responses. The responses will be stored electronically in a password protected folder. No hard copies will be kept. Following data collection and publication of the results all data will be destroyed.

Right to withdraw at any time:

Your participation is voluntary. You are free to withdraw your participation from this study at any time without penalty. If you do not want to continue, you can simply leave this website.

Please return the questionnaire to the researcher at the following address:

Joseph Castillo
Medical Imaging Department
Mater Dei Hospital

Contact information:

If you have concerns or questions about this study, please contact Joseph Castillo at joseph.castillo@gov.mt or the PhD project supervisor Prof Carmel J Caruana at carmel.j.caruana@um.edu.mt.

Consent to participate:

By participating in the survey, we acknowledge that you have read this information and have consented to participate and contribute to this research.

If you wish a summary of the results please leave your email address in the space provided within the demographic section.

Thank you.

Joseph Castillo

Appendix B – Semi-structured interview tool used in Objective 1

Interview Schedule

Objective 1: To develop a Service Portfolio for MRI services in Malta

Introduce oneself and project: My name is Joseph Castillo. As explained in the letter of invitation the end purpose of the study is to develop an inventory of biomedical imaging physics learning outcomes for MRI radiographers in Malta. In order to achieve this objective I need to identify present and envisaged future MRI service provision through the development of an MRI Service Portfolio for Malta. The study engages and consults with a broad range of MRI stakeholders including policy makers, patients' advocates, vendors, consultant radiologists, MRI radiographers, medical physicists and MRI services managers across Malta.

Definitions:

Service: clinical procedures, educational services to referrers (including self-referrals) and general public, service development oriented research activities.

Service Portfolio is defined as the complete set of services that are managed by a service provider. The service portfolio is used to manage the entire lifecycle of all services, and is made up of three service categories: service catalogue (i.e., services presently available or those ready for implementation), service pipeline (i.e., services being proposed and envisaged future development – both short term and long term in the case of this study means 2025), and services retired (i.e., to be deleted from the present services offered).

Importance of interviewee engagement: The information you provide is extremely valuable in ensuring that MRI radiographers would be capable of delivering present and future MRI services. Please answer the questions to the best of your knowledge. Most of the questions I will be asking may require multiple responses from you. Please provide all responses that come to mind. During the interview I may ask supplementary questions for further clarification.

Rights of the interviewee: As explained in the consent form the information you provide is completely confidential and will not be shared with anyone else without your consent. You may refuse to answer any question and may choose to stop the interview at any time.

Do you have any questions for me at this time?	Yes		No	
Do I have your agreement to proceed?	Yes		No	

Thank you. Let us begin. Record Time at beginning of interview _____:____

Section 1 – Introductory questions

- Can you describe briefly your personal background?
- Can you describe briefly your present role?
- What is the actual and potential impact of your present role on the present and future MRI portfolio at your institution?
- What is the actual and potential impact of your present role on the present and future MRI portfolio in Malta?

- What do you consider the relative strengths and weaknesses of MRI with respect to other imaging modalities such as CT and ultrasound?
- Regarding MRI scanning procedures, what percentage of patients received in your institution require urgent as opposed to pre-scheduled MRI scans? This question is important as radiographers would need to be able to use faster MRI sequences for urgent cases.
- Regarding educational services for referrers, who requests MRI services at your institution (give approximate percentages)? *This question is important as it impacts the extent and nature of educational services that would need to be provided for referrers including self-referrers.* What are your views about non-MD referrers and self-referrals in the case of MRI?

Consultant Physicians	
General Practitioners	
Non-MD Healthcare Professionals	
Self referrers	

- What is your opinion on the need of educational services for the general public regarding MRI? Do you consider these necessary, desirable?
- Regarding service development oriented research activities, are any research activities being carried out or planned to be carried out at your institution and which involve MRI? If yes what type of research activities? Do you see a need for such research? *This question is important as it would impact the level of imaging physics learning outcomes that would be required of MRI radiographers.*
- What is your opinion regarding outsourcing of MRI investigations? What do you think should be the criteria for deciding which procedures could be outsourced? How about public/private partnerships?
- What is your view regarding out of hours MRI provision? Would such a service be available continuously on a 24/7 formal rota or on an ad-hoc basis (no formal rota)? *This question is important to ascertain whether there are instances when radiographers would be working without the presence of radiologists.*
- (formal rota refers to a rota that is distributed in advance with a named radiologist / radiographer and contact details for each on-call period; ad-hoc refers to radiologist/radiographer who are not on call but may be available carry out the service)

Section 2 – Present MRI Service Catalogue (i.e., services presently available or those ready for implementation)

Which of the following MRI procedures is included in the service catalogue of your institution?

MRI procedure	Description
Neurological	MR Procedures of the brain and spine. In the brain this would include MR Pituitary, MR Orbits, MR Temporal lobe, MR Internal auditory meatii.
Body	MR procedure of Thorax, abdomen and Pelvis. In the abdomen and Pelvis this would include MR Liver,MR Pancreas, MR Kidneys, MR Rectum and MR Bladder.
Musculoskeletal	MR Appendicular skeleton and joints. This would include MR of long Bones and joints such as shoulder, elbow, wrist, sacroiliac, hip, knees, ankle and foot.
Vascular	Veins, and arteries using Time Of Flight (TOF), Phase Contrast (PC), Contrast Enhance Magnetic Resonance Angiography (CEMRA).
Breast	MRI of the breast in the assessment of pathology and implants
Cardiac	MRI of the heart to evaluate size, thickness of chambers, the extent

	of damage caused by heart attack and progressive heart disease
Magnetic Resonance CholangioPancreatography (MRCP)	MRI of the Biliary tree and pancreatic duct. This procedure is usually requested together with MR liver.
Guided Biopsy	Needle guided biopsy using MRI. This may be requested with MR of the breasts
Tractography	Procedure using elaborate DWI sequences to visualize the neural tracts of the brain. Usually requested with MR of the Brain.
Neurography	High resolution imaging of the nerve roots.
Prostate	Visualization of the prostate, seminal vesicles, retroperitoneum and bladder.
Female Pelvis	Investigate the Ovaries and Uterus and cervix
Paediatrics	Investigation mainly of brain and spine under general anesthesia
Oncology: general	Whole body MRI
MR Arthrography	creates images of one or more of the body's joints in order to evaluate its condition and to assist with the diagnosis and treatment of joint problems. A small amount of contrast is injected directly in the joint under fluoroscopy.
MR Urography	creates images of the kidneys, the ureters (tubes that transport urine from the kidneys to the bladder), and the bladder in order to evaluate their condition and to assist with the diagnosis and treatment of problems. MRI images similar to x-ray IVP are created by giving an MRI dye using intravenous drip. A diuretic is also given half way through the exam
MR enterography	Creates images of the small intestine. This procedure also use contrast medium to visualize the small intestine.
Spectroscopy	This procedure provides a measure of brain chemistry
Perfusion	Technique mainly used in stroke imaging to assess and measure cerebral perfusion via assessment of various hemodynamic measurements such as cerebral blood volume, cerebral blood flow, and mean transit time
Functional MRI	Location of locus of activation following stimulus or task using the Blood Oxygenated Level Dependent (BOLD) contrast technique.
Diffusion Weighted imaging (DWI)	A technique that enables the measurement of the restricted diffusion of water in tissue
Oncology: DWI	lymph node staging
MR Guided Focused Ultrasound (MRgFus)	technique that engages high intensity ultrasound beams to heat and destroy uterine fibroid tissue. This non-invasive surgical solution engages MR to visualize patient anatomy, map the volume of fibroid tissue to be treated and monitor the temperature of the tissue.
MRI Radiation therapy planning	Volumetric imaging that is used with other imaging modalities (fusion) to plan radiation,
MRI Surgery planning	Volumetric imaging that with software applications is used to plan surgery. Deep Brain stimulation is an example where volumetric imaging is used to implant electrodes in the brain.
Dedicated extremity system	MRI system dedicated specifically to image extremities with the patient totally outside the magnet.
Dedicated breast MRI system	MRI system specifically designed with 1) an ellipsoid magnetic shim that provides coverage of both breasts, the chest wall and bilateral axillary lymph nodes; 2) a patient-handling table that provides patient comfort and procedural utility; 3) a fully integrated Interventional System for MRI guided biopsy and localization; and 4) the use of computer-aided image display system to improve the accuracy and efficiency of diagnostic interpretations
Mobile MRI	MRI systems installed in Trailers that go to remote areas to provide MRI services thus reducing travelling times for patients. It could also be leased to address waiting lists
Open MRI	MRI systems that have one side of the bore opened to address

	claustrophobia and easy access during general anaesthesia.
Upright MRI	Upright open MRI scanners by which patients are scanned in standing (weight bearing) position. Used for ….
Emergency MRI	Protocols optimized to answer specific clinical questions in the shortest time possible
Sports service	Protocols optimized to assess sport related injuries

Which of the following referrer educational services are included in the Service Catalogue?

Consultant Physicians	Yes		No		
General Practitioners	Yes		No		
Non-MD Healthcare Professionals	Yes		No		
Self-referrers	Yes		No		

- Are educational services for the general public included in the Service Catalogue?
- Are any research activities included in the Service Catalogue?
- Is there an out of hours MRI provision at the facility? Is this service available continuously on a 24/7 formal rota or on an ad-hoc basis (no formal rota)?
- Do you have formal arrangements in place with other facilities to outsource MRI investigations? If yes which MRI examinations are outsourced and why?

Section 3 – Service Pipeline (short term and long term to 2020)

- Are there any services mentioned in section 2 which are not available at your institution but which you are considering introducing by 2020?
- What new or emerging MRI procedures are you aware of? Which of these services do you plan to introduce by 2020?
- Do you envisage changes in referral patterns e.g, more self-referrals or referrals by non-MD healthcare professionals by 2020? Do you think an educational campaign for these healthcare professionals and for the self-referrers would need to be organized by your institution?
- Would any/new educational services for the general public be included in the Service Pipeline by 2020?
- Would any any/new research activities be included in the Service Pipeline by 2020?

Section 4 – Service retired

- Are there any MRI services which the institution has sidelined or would be sidelining by 2020? Why will these services no longer be offered?

Section 5 – Concluding the interview

- I appreciate the time you took for this interview. Is there anything else that you think would be helpful for me to know?
- Do you have any documentation for me that might of help in the project or that would support your responses during this interview?
- I should have all the information I need. Would it be alright to check the interview manuscript when this is fully transcribed?

Thank you once more

Appendix C – Second round Delphi web-based questionnaire used in Objective 1

2020 Vision MRI service portfolio for Malta - Delphi Round 2

Information and Consent

Dear Participant,
Thank you for having participated in the interviews. From your responses I have been able to identify more clearly what you as MRI stakeholders experts believe to be the important components of a 2020 vision for the MRI service portfolio for Malta. The responses were analyzed using thematic analysis, concept maps and NVIVO10 and a number of statements were developed and grouped under the following themes.

• technical expertise
• current procedures
• future services
• future technology
• accessibility of services
• patient education
• employee education
• legislation
• safety considerations

The aim of this Round 2 Delphi questionnaire is to quantify the degree of agreement amongst you. This questionnaire should only take about 30 minutes to complete. Please do fill in this Delphi survey even if you were unable to participate in the previous interview. You also have the opportunity to include any additional views that you might have and which have not been included in this questionnaire.

Benefits of the study:
You will be contributing to the development of a 2020 vision for the MRI service portfolio for Malta. This vision will be used to develop physics learning outcomes for MRI radiographers.

Confidentiality:
Your responses will be kept completely confidential. I will NOT know your IP address. I ask you to include your name simply so that I may correlate your answers to this survey with the data I collected from the previous interviews. You will be assigned a participant number and only the participant number will appear in the dissertation. Only the researcher will see your individual survey responses. The responses will be stored electronically in a password protected folder. No hard copies will be kept. Following data collection and publication of the results all data will be destroyed.

Right to withdraw at any time:
Your participation is voluntary. You are free to withdraw your participation from this study at any time without penalty. If you do not want to continue, you can simply leave this website.
If you do not click on the "submit" button at the end of the survey, your answers and participation will not be recorded.

Contact information:
If you have concerns or questions about this study, please contact Joseph Castillo at joseph.castillo@gov.mt or the PhD project supervisor Prof Carmel J Caruana at

carmel.j.caruana@um.edu.mt.

Consent to participate

By taking the survey, you acknowledge that you have read this information and have consented to participate in this research.

Thank you.
Joseph Castillo

2020 Vision MRI service portfolio for Malta - Delphi Round 2

2020 Vision MRI Service Portfolio for Malta - 2nd round

1. Demographic Information of Respondent (confidentiality is guaranteed).

Name:

Place of employment

Present role within place of employment

2020 Vision MRI service portfolio for Malta - Delphi Round 2

Current MRI Service Catalogue

Please read the statements below regarding the current MRI Service Catalogue and rank the level of agreement or disagreement

2. Neurology MRI including Diffusion weighted imaging should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

3. Body MRI should continue to form part of MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

4. Musculoskeletal MRI should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

5. Vascular MRI should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

6. Breast MRI should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
◯	◯	◯	◯	◯	◯

Comment

7. MR Cholangiopancreatography (MRCP) should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
◯	◯	◯	◯	◯	◯

Comment

8. MR Neurography (e.g Brachial plexus) should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
◯	◯	◯	◯	◯	◯

Comment

9. MRI prostate imaging should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
◯	◯	◯	◯	◯	◯

Comment

10. MRI female pelvis should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
◯	◯	◯	◯	◯	◯

Comment

11. Paediatric MRI should continue to form part of the MRI service catalogue

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

12. MRI with general anaesthesia should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

13. MR arthrography should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

14. MRI planning for Deep Brain Stimulation should continue to form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

15. On call services should continue to be provided on a 24 / 7 basis.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

16. Outsourcing should only be considered after all other options in reducing the waiting time have failed.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

2020 Vision MRI service portfolio for Malta - Delphi Round 2

MRI Service Pipeline

These are the services in development or proposed for possible inclusion into the 2020 MRI service catalogue by one or more participants in the first round of the Delphi.

Please read the statements below concerning the MRI service pipeline and rank the level of agreement and disagreement.

17. By 2020, information on the diagnostic utility of different pulse sequences in the various areas of healthcare should be provided to healthcare professionals.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

18. By 2020, information on MRI legislation should be provided to all healthcare professionals.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

19. By 2020, evidence based referral guidelines should be made available to all MRI stakeholders.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

20. By 2020, information about the strengths, limitations and safety of MRI should be made available to the general public.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

comment

21. By 2020, MRI courses should be developed for MD and non-MD referrers.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

comment

22. By 2020, all referrers should be certified in MRI referral before being granted MRI referring privileges.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

23. By 2020, MRI education to all professions involved in MRI should be quality assured.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

24. By 2020, all professions involved with MRI should participate in research.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

25. By 2020, local MRI departmental regulations and procedures should be constantly updated to any EU legislation and documentation.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

26. By 2020, referral guidelines would be used to prioritize accessibility to services.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

27. By 2020, standard operating procedures regulating non-MD referrals would be needed as non-MD referrals will become more common.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

28. By 2020, MR tractography (MRI of neural tracts of the brain) should form part of the MRI Service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

29. By 2020, 3T Imaging should form part of the MRI Service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

30. By 2020, MRI guided biopsy of the breast should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

31. By 2020, diffusion weighted imaging for non cerebral work should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

32. By 2020, cardiac MRI should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

33. By 2020, breast MRI as a screening tool for family screening should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

34. By 2020, oncology planning with MRI fusion imaging should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

35. By 2020, MRI-PET should form part of the MRI service portfolio.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

36. By 2020, Elastography imaging which is used for evaluating liver cirrhosis should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

37. By 2020, dynamic MRI for patellar tracking should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

38. By 2020, MRI enterography (small intestine imaging) should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

39. By 2020, Prostate MRI as a screening tool should form part of the MRI service catalogue.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

40. By 2020, assessment of change in tumour burden as a measure of treatment response or tumour progression should form part of the MRI service portfolio.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

41. The quality and safety of the MRI service should be ISO assured.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

42. Are there any other services which should be included in the present MRI service catalogue

2020 Vision MRI service portfolio for Malta - Delphi Round 2

MRI services to be sidelined.

These refer to present MRI services that should be sidelined in preference to other modalities.

43. Given the present level provision of MRI services in Malta none of the present services should be sidelined.

completely disagree	generally disagree	slightly disagree	slightly agree	generally agree	completely agree
○	○	○	○	○	○

Comment

2020 Vision MRI service portfolio for Malta - Delphi Round 2

Final comments

44. Are there any other comments which you would like to make?

Thank you for helping me in my research

Appendix D – NGT User Guide Version 5 used in Objective 2

The Meeting Venue
The meeting venue may be at a leading hotel. The room will be set up with tables in a U-shape, with a flip chart at the open end of the U. Managerial and patient contact group members would be seated alternately for enhanced interaction between the two groups.

Supplies

Flip chart, a roll of masking tape, a pack of index cards (approx 8 cards per person), one large felt-tip pen for marking on flip chart, and paper and pencil for each participant.

Opening Statement
The statement will clarify member roles and group objectives and includes a warm welcome, a statement of the importance of the task, the importance of each member's contribution, and an indication of how the group's output will be used. The core values guiding the project will also be explained to the participants.

Outline what has been achieved so far and the purpose of this study. Read out the consent form emphasizing confidentiality and the right to retire from the session.

Describe patient / referrer preferences regarding the organization and delivery of the MRI service

CONDUCTING THE SESSION

The main objective of the NGT meeting is to have group members write key ideas silently and independently. This is done to:

Provide:

A. adequate time for thinking and reflection
B. social facilitation from seeing others working on the same task
C. sufficient time for generation of ideas
D. the benefit of remaining problem-centred

Avoid:

A. interruptions
B. competition, status pressures, and conformity pressures
C. choosing between ideas prematurely

To accomplish this step, the researcher will:

- Present the questions to the group in written form.
- Verbally read the question to the group.
- Direct the group to write ideas in brief phrases or statements.
- Ask the group to work silently and independently.

Round-Robin Recording of Ideas

Draw a circle representing the cycle of service on the flip chart. Record the ideas of group members on a flip chart visible to the entire group. In this context round-robin recording refers to the process of asking for one idea from one member at a time. The researcher writes the idea of a group member on the flip chart and then proceeds to ask for one idea from the next group member, and so on.

Action:

1. Number and record each idea on the cycle of service.
2. Allow a person to "pass" if they have no new ideas (but allow them to re-enter later, if they wish).
3. Record ideas as rapidly as possible.
4. Record ideas in the exact words of the group member.
5. Make the entire list of ideas visible to the entire group.
6. Allow only a listing of ideas, not a discussion or debate.

Discuss each idea in turn for the purpose of clarification. Advantages of this step include:

- Avoids focusing unduly on any one idea or subset of ideas.
- Provides an opportunity for clarification and elimination of misunderstanding.
- Provides an opportunity to present the logic behind an idea or disagreement.
- Allows for recording of differences of opinion without undue argumentation.

PRELIMINARY VOTE ON THE MOST IMPORTANT POSITIVE EXPERIENCES

The purpose of this step is to aggregate the judgments of individual members to determine the relative importance of individual items. The procedure is as follows:

- Step 1

  Each participant selects the ten most important items from the list of statements and record (1 to 10) them separately on a worksheet or index card.

- Step 2

  The ranking for each individual statement are summed to give a total score.

IDENTIFY THE RESOURCES NECESSARY TO DELIVER A POSITIVE EXPERIENCE

The top 15 statements are presented to the group for discussion. Facilitator only intervenes to direct focus.

Participants then individually rank the most important 10 issues. This time a weighting is assigned to each item 100 is highest weighting and 1 is the least.

The final list of 10 ranked statements are presented.

(g) FINAL DISCUSION

A brief discussion is held after the group sees the ratings of the entire group. This discussion focuses on those ideas that were most highly rated during the preliminary vote and again concentrates on clarification of the issues.

Appendix E - Web based questionnaire used in Objective 3

Present status of MRI qualification, certification and registration, competence profile

Dear participant,

The aim of this web based questionnaire is to investigate the present status of MRI qualification, certification and registration in the major English speaking countries. This questionnaire should only take about 30 minutes to complete.

Benefits of the study:
The results of this questionnaire will be published. You will be helping the profession get an overview of the present state of affairs regarding MRI qualification, certification, competence profiles and registration.

Confidentiality:
Your responses will also help me in my PhD dissertation. Your responses will be kept completely confidential. You will be assigned a participant number and only the participant number will appear in the dissertation. Responses will be anonymised by setting the software to hide IP addresses. The responses will be stored electronically in a password protected folder. No hard copies will be kept. Following data collection and publication of the results all data will be destroyed.

Right to withdraw at any time:
Your participation is voluntary. You are free to withdraw your participation from this study at any time without penalty. If you do not want to continue, you can simply leave this website.

If you do not click on the "submit" button at the end of the survey, your answers and participation will not be recorded.

Contact information:
If you have concerns or questions about this study, please contact Joseph Castillo at joseph.castillo@gov.mt or the PhD project supervisor Prof Carmel J Caruana at carmel.j.caruana@um.edu.mt.

Consent to participate:
By participating in the survey, you acknowledge that you have read this information and have consented to participate and to contribute to this research.

If you wish to receive a summary of the results please leave your email address in the space provided within the demographic section.

Thank you.
Joseph Castillo

Present status of MRI qualification, certification and registration, competence profile

1. Demographic Information of Respondents (confidentiality guaranteed)

Country in which you practice:

Type of Institution you practice in:

Present role within place of employment:

Present status of MRI qualification, certification and registration, competence profile

Part A: MRI Qualifications

2. Is there a nationally approved MRI education programme?

3. If there is no nationally approved MRI education, how is MRI education provided? multiple answers possible

- [ ] Part of Undergraduate training
- [ ] In-house hospital based
- [ ] Courses run by private agency
- [ ] Courses run by a professional radiography society

4. Are the centres / institutions for MRI education externally accredited?

- ○ Yes
- ○ No

5. What type of accreditation?

- ○ Institutional
- ○ Programme
- ○ Both

6. Who provides the accreditation?

7. Does it lead to any formal qualification?

- ○ Yes
- ○ No

8. What is the name of this qualification in native language and in English?

9. Are the theoretical education and clinical training programme curricula the same in all centres of education in the country?

◯ Yes

◯ No

10. What pre-requisite qualifications are required to be accepted for this MRI education and training programme?

11. Where does the education and training take place?

◯ University site

◯ Hospital site

◯ Both

12. If BOTH who is responsible for student supervision and assessment?

13. How long is the programme in months? (specify the total time spent at each site)

14. What is the process for assessing the training? examination, CPD portfolio, other? Please give a brief description

15. Who carries out the assessment?

◯ University

◯ Hospital

◯ Both

Present status of MRI qualification, certification and registration, competence profile

Part B: Certification and competence profile

16. Is a formal qualification required for certification to practice as MRI radiographer / technologist in your country?

- ◯ Yes
- ◯ No

17. Do you need to be Radiographer / Technologist to practice MRI?

18. Is certification required to be allowed to practice in MRI in your country?

- ◯ Yes
- ◯ No

19. If the answer to the previous question is 'Yes', who provides the certification to practice in MRI?

20. Is it the only way to become eligible to practice in MRI? Describe other pathways that may be used

21. Is the certification based on a formal national MRI competence profile?

- ◯ Yes
- ◯ No

22. If 'Yes' which authority / institution develops the MRI competence profile?

23. If 'No' is there a hospital MRI competence profile?

- ◯ Yes
- ◯ No

24. How was this MRI competence profile developed?

Present status of MRI qualification, certification and registration, competence profile

Part C: Registration

25. Is there a Register of MRI radiographers / technologists in the country?

- ◯ Yes
- ◯ No

26. Which authority / institution maintains the register?

27. Is listing in the Register voluntary or compulsory?

- ◯ Voluntary
- ◯ Compulsory

28. Does registration identify various levels of registrants?

- ◯ Yes
- ◯ No

29. How many levels and what are they called?

30. What are these levels based on? Degrees, competency, certificates, exams, other?

31. Does the Register have a special procedure for recognition of other professionals registered as MRI radiographers / technologists in other countries?

- ◯ Yes
- ◯ No

32. Is there a renewal mechanism in the Register?

- ◯ Yes
- ◯ No

33. How long is the re-registration period?

34. On what criteria is the renewal mechanism based? CPD portfolio, examination, both, other? please describe method of renewal.

35. Email address for summary of results

Thank you for your time and support

Appendix F - list of textbook and articles used to develop knowledge and skill statements used in Objective 5

Alam, M. H., D. Auger, G. C. Smith, T. He, V. Vassiliou, A. J. Baksi, R. Wage, P. Drivas, Y. Feng and D. N. Firmin (2015). "T1 at 1.5 T and 3T compared with conventional T2* at 1.5 T for cardiac siderosis." Journal of Cardiovascular Magnetic Resonance **17**(1): 102.

Allen, B. C. and J. R. Leyendecker (2013). "Placental evaluation with magnetic resonance." Radiologic Clinics of North America **51**(6): 955-966.

Allen, B. C. and J. R. Leyendecker (2014). "MR enterography for assessment and management of small bowel Crohn disease." Radiologic Clinics of North America **52**(4): 799-810.

Amzallag-Bellenger, E., A. Oudjit, A. Ruiz, G. Cadiot, P. A. Soyer and C. C. Hoeffel (2012). "Effectiveness of MR enterography for the assessment of small-bowel diseases beyond Crohn disease." Radiographics **32**(5): 1423-1444.

Angthong, W. and R. C. Semelka (2014). "Dealing with vascular conundrums with MR imaging." Radiologic Clinics of North America **52**(4): 861-882.

Ayache, J. B. and J. D. Collins (2014). "MR angiography of the abdomen and pelvis." Radiologic Clinics of North America **52**(4): 839-859.

Balci, N. C., R. C. Semelka and E. Altun (2006). "Fundamentals of MR imaging techniques applied to the abdomen and the pelvis." Applied Radiology **35**(12): 30-35.

Bhatti, L., J. K. Hoang, B. M. Dale and M. R. Bashir (2015). "Advanced magnetic resonance techniques: 3 T." Radiologic Clinics of North America **53**(3): 441-455.

Bieri, O. and K. Scheffler (2013). "Fundamentals of balanced steady state free precession MRI." Journal of Magnetic Resonance Imaging **38**(1): 2-11.

Biglands, J. D., A. Radjenovic and J. P. Ridgway (2012). "Cardiovascular magnetic resonance physics for clinicians: Part II." Journal of Cardiovascular Magnetic Resonance **14**(1): 66 - 106.

Braun, H. J., J. L. Dragoo, B. A. Hargreaves, M. E. Levenston and G. E. Gold (2013). "Application of advanced magnetic resonance imaging techniques in evaluation of the lower extremity." Radiologic Clinics of North America **51**(3): 529-545.

Carneiro, A., G. Vilela, D. de Araujo and O. Baffa (2006). "MRI relaxometry: methods and applications." Brazilian journal of physics **36**(1A): 9-15.

Chang, I.-Y. J. and J. M. Polster (2016). "Pathomechanics and magnetic resonance imaging of the thrower's shoulder." Radiologic Clinics of North America **54**(5): 801-815.

Cogley, J. R. and F. H. Miller (2014). "MR imaging of benign focal liver lesions." Radiologic Clinics of North America **52**(4): 657-682.

Crema, M. D., F. W. Roemer, M. D. Marra, D. Burstein, G. E. Gold, F. Eckstein, T. Baum, T. J. Mosher, J. A. Carrino and A. Guermazi (2011). "Articular Cartilage in the Knee: Current MR Imaging Techniques and Applications in Clinical Practice and Research 1." Radiographics **31**(1): 37-61.

Davarpanah, A. H. and G. M. Israel (2014). "MR imaging of the kidneys and adrenal glands." Radiologic clinics of North America **52**(4): 779-798.

De Wilde, J., D. Grainger, D. Price and C. Renaud (2007). "Magnetic resonance imaging safety issues including an analysis of recorded incidents within the UK." Progress in Nuclear Magnetic Resonance Spectroscopy **51**(1): 37-48.

De Wilde, J., A. Rivers and D. Price (2005). "A review of the current use of magnetic resonance imaging in pregnancy and safety implications for the fetus." Progress in biophysics and molecular biology **87**(2): 335-353.

Dewhurst, C. E. and K. J. Mortele (2013). "Magnetic resonance imaging of rectal cancer." Radiologic clinics of North America **51**(1): 121-131.

Elster, A. D. (1994). Questions and answers in magnetic resonance imaging. St. Louis: Mosby-Year Book, Inc.

François, C. J. (2015). "Current state of the art cardiovascular MR imaging techniques for assessment of ischemic heart disease." Radiologic Clinics of North America **53**(2): 335-344.

Fraum, T. J., K. J. Fowler, J. McConathy, E. E. Parent, F. Dehdashti, P. W. Grigsby and B. A. Siegel (2015). "PET/MRI for the body imager: abdominal and pelvic oncologic applications." Abdominal imaging **40**(6): 1387-1404.

Grand, D. J., M. Beland and A. Harris (2013). "Magnetic resonance enterography." Radiologic Clinics of North America **51**(1): 99-112.

Graves, M. and S. Reid (2012). "Non-contrast enhanced vascular imaging with MRI." RAD Magazine 2012 May; 38 (444): 17 **8**.

Griffith, B. and R. Jain (2016). "Perfusion imaging in neuro-oncology: basic techniques and clinical applications." Magnetic resonance imaging clinics of North America **24**(4): 765-779.

Guglielmo, F. F., D. G. Mitchell and S. Gupta (2014). "Gadolinium contrast agent selection and optimal use for body MR imaging." Radiologic Clinics of North America **52**(4): 637-656.

Gümüştaş, S., N. Inan, G. Akansel, E. Çiftçi, A. Demirci and S. Özkara (2012). "Differentiation of malignant and benign lung lesions with diffusion-weighted MR imaging." Radiology and oncology **46**(2): 106-113.

Gupta, A., N. Subhas, A. N. Primak, M. Nittka and K. Liu (2015). "Metal artifact reduction: standard and advanced magnetic resonance and computed tomography techniques." Radiologic clinics of North America **53**(3): 531-547.

Gupta, R. T., C. R. Kauffman, T. J. Polascik, S. S. Taneja and A. B. Rosenkrantz (2013). "The State of Prostate MRI in 2013." Oncology **27**(4): 262-270.

Hendrick, R. E. (2014). "High-quality breast MRI." Radiologic Clinics of North America **52**(3): 547-562.

Hope, T. A., M. A. Ohliger and A. Qayyum (2014). "MR imaging of diffuse liver disease: from technique to diagnosis." Radiologic Clinics of North America **52**(4): 709-724.

Kaproth-Joslin, K. and V. Dogra (2013). "Imaging of female infertility: a pictorial guide to the hysterosalpingography, ultrasonography, and magnetic resonance imaging findings of the congenital and acquired causes of female infertility." Radiologic Clinics of North America **51**(6): 967-981.

Kim, B. S., W. Angthong, Y.-H. Jeon and R. C. Semelka (2014). "Body MR imaging: fast, efficient, and comprehensive." Radiologic Clinics of North America **52**(4): 623-636.

Lalwani, N., M. Moshiri, J. H. Lee, P. Bhargava and M. K. Dighe (2013). "Magnetic resonance imaging of pelvic floor dysfunction." Radiologic Clinics of North America **51**(6): 1127-1139.

Lim, R. P. and I. Koktzoglou (2015). "Noncontrast magnetic resonance angiography: concepts and clinical applications." Radiologic Clinics of North America **53**(3): 457-476.

Lomasney, L. M., H. Choi and N. Jayanthi (2013). "Magnetic resonance arthrography of the upper extremity." Radiologic Clinics of North America **51**(2): 227-237.

Lombardi, M. and C. Bartolozzi (2005). MRI of the Heart and Vessels, Springer Science & Business Media.

Maglinte, D. D. T., & Rubesin, S. Advances in intestinal imaging. Radiologic clinics*, 41*(2), xi-xii.

Mannelli, L., S. Nougaret, H. A. Vargas and R. K. Do (2015). "Advances in diffusion-weighted imaging." Radiologic clinics of North America **53**(3): 569-581.

McRobbie, D. W., E. A. Moore and M. J. Graves (2017). MRI from Picture to Proton, Cambridge university press.

Medicines and Healthcare Regulatory Agency (MHRA) (2014). Safety guidelines for magnetic resonance imaging equipment in clinical use**:** 85.

Messroghli, D. R., A. Radjenovic, S. Kozerke, D. M. Higgins, M. U. Sivananthan and J. P. Ridgway (2004). "Modified Look-Locker inversion recovery (MOLLI) for high-resolution T1 mapping of the heart." Magnetic Resonance in Medicine **52**(1): 141-146.

Middleton, M. S. (2014). "MR evaluation of breast implants." Radiologic Clinics of North America **52**(3): 591-608.

Frank M. H. (2002) Radiology of the pancreas, gallbladder, and biliary tract, Radiologic Clinics of North America 40(6)

Morelli, J. N., C. M. Gerdes, P. Schmitt, T. Ai, M. R. Saettele, V. M. Runge and U. I. Attenberger (2013). "Technical considerations in MR angiography: An image-based guide." Journal of Magnetic Resonance Imaging **37**(6): 1326-1341.

Motoshima, S., H. Irie, T. Nakazono, T. Kamura and S. Kudo (2011). "Diffusion-weighted MR imaging in gynecologic cancers." Journal of gynecologic oncology **22**(4): 275-287.

Moy, M. P., Sauk, J., & Gee, M. S. (2016). The Role of MR Enterography in Assessing Crohn’s Disease Activity and Treatment Response. *Gastroenterology Research and Practice,* pages: 13.

MRI Working Group. (2008). "Using MRI Safely - practical rules for employees."   Retrieved 3rd June, 2010, from http://docs.minszw.nl/pdf/92/2008/92_2008_1_22102.pdf.

O'Neill, E., N. Hammond and F. H. Miller (2014). "MR imaging of the pancreas." Radiologic clinics of North America **52**(4): 757-777.

Olsen, Ø. E. (2008). "Practical body MRI—A paediatric perspective." European journal of radiology **68**(2): 299-308.

Partovi, S., H. von Tengg-Kobligk, N. Bhojwani, C. Karmonik, M. Maurer and M. R. Robbin (2015). "Advanced noncontrast MR imaging in musculoskeletal radiology." Radiologic Clinics of North America **53**(3): 549-567.

Patel, C. M., A. Sahdev and R. H. Reznek (2011). "CT, MRI and PET imaging in peritoneal malignancy." Cancer Imaging **11**(1): 123-139.

Pfeiffer, R. P., M. DeBeliso, K. G. Shea, L. Kelley, B. Irmischer and C. Harris (2004). "Kinematic MRI assessment of McConnell taping before and after exercise." The American journal of sports medicine **32**(3): 621-628.

Ridgway, J. P. (2010). "Cardiovascular magnetic resonance physics for clinicians: part I." Journal of cardiovascular magnetic resonance **12**(1): 71 - 111.

Sanchis-Alfonso, V. (2011). Anterior knee pain and patellar instability, Springer Science & Business Media.
Sandrasegaran, K. (2014). "Functional MR imaging of the abdomen." Radiologic Clinics of North America **52**(4): 883-903.

Schick, F. (2005). "Whole-body MRI at high field: technical limits and clinical potential." European radiology **15**(5): 946-959.

Society of Radiographers (2013). Safety in Magnetic Resonance Imaging. Alexandra Lipton.

Soh, E., P. W. Bearcroft, M. J. Graves, R. Black and D. J. Lomas (2008). "MR-guided direct arthrography of the glenohumeral joint." Clin Radiol **63**(12): 1336-1341; discussion 1342-1333.

Soldatos, T., G. Andreisek, G. K. Thawait, R. Guggenberger, E. H. Williams, J. A. Carrino and A. Chhabra (2013). "High-Resolution 3-T MR Neurography of the Lumbosacral Plexus." RadioGraphics **33**(4): 967-987.

Surabhi, V. R., C. O. Menias, V. George, C. L. Siegel and S. R. Prasad (2013). "Magnetic resonance imaging of female urethral and periurethral disorders." Radiologic Clinics of North America **51**(6): 941-953.

Westbrook, C. (2014). Handbook of MRI technique, John Wiley & Sons.

Westbrook, C. (2016). MRI at a glance, John Wiley & Sons.

Westbrook, C. and C. K. Roth (2011). MRI in Practice, John Wiley & Sons.

Woodward, P. (2000). MRI for Technologists, The McGraw-Hill Companies.

Yacoub, J. H., A. Oto and F. H. Miller (2014). "MR imaging of the prostate." Radiologic Clinics of North America **52**(4): 811-837.

Yam, B. L. and E. S. Siegelman (2014). "MR imaging of the biliary system." Radiologic Clinics of North America **52**(4): 725-755.

Zanzonico, P. (2004). Positron emission tomography: a review of basic principles, scanner design and performance, and current systems. In *Seminars in nuclear medicine* 34,(2) 87-111.

Ziegler, S. I. (2005). "Positron emission tomography: principles, technology, and recent developments." Nuclear Physics A **752**: 679-687.

Appendix G – Initial inventory of physics learning outcome with professional group responses

RG = Radiographer RD = Radiologist MP = Medical Physicist	Knowledge (K) / Skill (S) / Competence statements	Participants in favour				
		RG	RD	MP	Total	%
Fundamental biomedical Physics knowledge and skills GENERIC to ALL competences						
K1. Explain the basic laws of electromagnetism, relative magnitudes of electronic and nuclear magnetic dipoles, magnetic polarization, susceptibility and its different forms (electronic diamagnetism, paramagnetism, ferromagnetism; nuclear paramagnetism) and their relevance to MRI (classical description, basic quantum description)		5	4	3	12	80.00
K2. Distinguish between magnet types (permanent, resistive, superconducting, hybrid, niche) and advantages/disadvantages of each		5	4	4	13	86.67
K3. Explain the basic physical properties of tissue for generating tissue contrast (SD, T1, T2, T2*, diffusion)		5	5	5	15	100.00
K4. Explain how an MRI signal is produced and weighted in SE, GRE sequences		5	5	5	15	100.00
K5. Explain the appearance of a given MR image in terms of the relevant basic physical properties of normal/ pathological tissue, including the effect of contrast agents		5	5	5	15	100.00
K6. Explain the use of preparation pulses (e.g., inversion recovery, fat saturation, steady state) and their use in modified sequences e.g., how inversion time is selected to suppress signal from a specific type of tissue.		5	5	5	15	100.00
K7. Explain the need for the various types of RF coil (volume, surface local, surface arrays, internal), coil tuning, transmit and receive bandwidth		5	5	5	15	100.00
K8. Explain use of gradient coils for slice selection and 2D/3D spatial encoding including gradient amplitude, rise time, slew rate, duty cycle, k-space as MR data space and k-space filling.		5	4	5	14	93.33
K9 Define and explain the relationship between the various image quality criteria (e.g., sharpness, conspicuity of detail) and basic device performance parameters (e.g., SNR, CNR, SR, field homogeneity) in MRI		5	5	5	15	100.00

K10. Explain the various ways of reducing scan time e.g., fast sequences, partial k-space filling and associated trade-offs. Explain parallel imaging, effect of number of coil receive elements, and parallel imaging factor selection and direction relative to the coil elements.	5	4	5	14	93.33
K11. Explain the various types of MR image artefacts and ways of avoiding or compensating for these.	5	5	5	15	100.00
K12. Explain physical aspects of patient and occupational safety in MRI including bioeffects, tissue heating, SAR, fringe field and safety zones, noise protection, pregnancy and paediatrics, examinations requiring particular caution.	5	5	5	15	100.00
K13. Explain the principles of Magnetic Resonance Spectroscopy (MRS), why good signal-to-noise (SNR) in MRS is critical and how it may be optimised	2	5	5	12	80.00
K14. Explain the principles of Chemical Shift Imaging (CSI	4	4	2	10	66.67
K15. Discuss the relative advantages and disadvantages of MRI at 1.5T and 3T	5	5	4	14	93.33
K16. Understand the importance of consulting with other MRI stakeholders before applying changes in scanning protocols that would affect image quality or patient safety	5	5	5	15	100.00
S1. Screen patients/visitors/personnel and ancillary devices for ferrous/ RF-sensitive material prior to entrance into magnetic field	5	5	5	15	100.00
S2. Select (including the identification of specific transmit coils from receive-only coils and the safety implications), set-up and position appropriate RF coils for a given study.	5	5	5	15	100.00
S3. Select parallel imaging factor and direction relative to the coil elements	4	4	5	13	86.67
S4. Manipulate pulse control and operator units, landmark, acquire scout image, prescribe slices and saturation bands, scan patient	5	5	5	15	100.00
S5. Review relevant clinical information and records to determine examination technical requirements	5	5	4	14	93.33
S6. Select appropriate examination protocol and acquisition parameters (e.g., TR, TE, FOV, slice thickness) to achieve target image quality criteria required by the clinical question and any patient requirements	5	4	5	14	93.33
S7. Select protocol options (e.g., saturation pulse, fat suppression) to maximize diagnostic effectiveness	4	4	5	13	86.67

S8. Adjust parameters or sequence to maintain SAR values within acceptable limits	5	5	4	14	93.33
S9. Select alternative sequences to avoid/reduce artefacts (e.g., metal implant artifacts, susceptibility artifacts, flow compensation)	5	5	5	15	100.00
S10. Modify the examination according to the resultant findings and clinical presentation	4	5	4	13	86.67
S11. Monitor image quality outcomes and distinguish between technically acceptable and unacceptable images	5	5	5	15	100.00
S12. Perform appropriate image post-processing	5	5	4	14	93.33
S13.Setup power injector including setting of appropriate dose according to patient weight	5	5	5	15	100.00
S14. Consult with other MRI stakeholders before applying changes in scanning protocols that would affect image quality or patient safety	5	5	5	15	100.00
Competence IA1: Assumes responsibility for the planning and execution of Neurology MRI including Diffusion Weighted Imaging, Magnetic Resonance Angiography, MRI tractography, MRI Neurography. Planning for Deep Brain Stimulation is carried out under neurosurgeon's supervision.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the T2-FLAIR sequence and its use in brain imaging	5	5	5	15	100.00
K2. Define diffusion and describe qualitatively the effect of tissue microstructure on rate of diffusion. Explain molecular diffusion rate (Mean Diffusivity (MD) or Apparent Diffusion Coefficient (ADC)).	4	5	5	14	93.33
K3. Explain how the MR signal is sensitised to diffusion, definition of b- value.	5	5	5	15	100.00
K4. Explain how the visualization of pathological processes is influenced by the choice of b-values.	5	4	4	13	86.67
K5. Explain common artefacts in DWI (e.g., T2 shine-through, eddy currents, bulk head motion, CSF pulsations, solid/soft tissue interfaces) and solutions e.g., use of Single Shot EPI.	5	4	5	14	93.33
K6. Distinguish between isotropic and anisotropic diffusion in the brain, the directional preference of diffusion (Fractional Anisotropy (FA)), axial and radial diffusivities.	4	4	3	11	73.33
K7. Explain the principles of Diffusion Tensor Imaging (DTI) and white matter tractography	5	4	4	13	86.67

K8. Explain the need for high b-values, need for a minimum of 6 non-collinear diffusion encoding directions, basic calculation of optimal b-value.	5	3	2	10	66.67
K9. Provide a basic interpretation of ellipsoid glyphs, diffusion tensor, eigenvalues, eigenvectors	2	2	1	5	33.33
K10. Explain the principles of conventional brain MRA (time-of-flight, phase contrast, contrast enhanced, black and bright blood).	5	5	5	15	100.00
K11. Explain the principles of MR Neurography (MRN)	4	5	4	13	86.67
K12. Explain the principles of magnetization transfer imaging (MTI)	4	4	4	12	80.00
S1. Set up a head coil.	5	5	5	15	100.00
S2. Set up brain sequences including T2-FLAIR, DWI, DTI and higher resolution ROIs.	5	5	4	14	93.33
S3. Select/adjust b-values to maximize diagnostic effectiveness of DWI and DTI protocol	4	4	5	13	86.67
S4. Select/adjust number and direction of diffusion encoding gradients to maximize diagnostic effectiveness of DTI protocol	2	5	4	11	73.33
S5. Use DWI and DTI software to provide scalar and tensor maps	4	4	3	11	73.33
S6. Select/adjust TE values to maximize diagnostic effectiveness of MRN protocol	3	5	4	12	80.00
S7. Select the appropriate MRA protocol to improve diagnosis	5	4	5	14	93.33
S8. Set up flip angle, TR, TE values and MT in MRA sequences to enhance time of flight effects from arteries.	3	5	4	12	80.00
S9. Select/adjust VENC values to maximize diagnostic effectiveness of phase contrast MRA	4	5	4	13	86.67
S10. Select the appropriate bolus chasing technique to synchronize the acquisition of the central portion of k-space with the arrival of the contrast bolus.	5	5	4	14	93.33
S11. Perform multiplanar reconstructions in any arbitrary imaging plane as discussed with the reporting Radiologist.	5	5	5	15	100.00
Competence IA2: Assumes responsibility for the planning and execution of Body MRI including Diffusion Weighted	Participants in favour				

Imaging, Magnetic Resonance Angiography (MRA) and MR Enterography (MRE).	RG	RD	MP	Total	%
K1. Explain the principles of half-Fourier acquisition with single shot fast SE acquisitions (T2W) and its use in clinical practice.	4	4	4	12	80.00
K2. Explain the principles of balanced steady state free precession (BSSFP) and its use in rapid morphological imaging.	3	4	3	10	66.67
K3. Explain the principles of T1W dual echo (in phase, out of phase) Spoiled Gradient Echo (SGE) acquisitions; fat suppressed SGE and 3D Gradient Echo.	5	4	5	14	93.33
K4. Discuss the advantages and disadvantages of using respiratory gated / cardiac gated SS-EPI DWI in Body MRI	5	5	5	15	100.00
K5. Explain the principles of fat-suppressed T1-weighted three-dimensional gradient recalled echo sequence	5	4	4	13	86.67
K6. Explain the principles of motion resistant protocols (MP-RAGE sequence; 3D Radial GRE sequence; single shot echo train SE)	4	5	5	14	93.33
K7. Explain how the artefacts associated with abdominal imaging (respiratory motion, intrinsic motion, chemical shift, susceptibility artefacts) can be reduced by utilizing faster gradients, breath-hold sequences and fat suppression techniques.	5	5	5	15	100.00
K8. Explain the relevance of low and high ‘b’ values in the investigation of diseases of the liver, pancreas, urinary tract and bowel.	3	5	3	11	73.33
K9. Explain the relevance of DWI and associated ADC maps to investigate high and low cellularity of tumours.	2	5	3	10	66.67
K10. Explain the principles of MRE including fat suppression and DWI	4	5	3	12	80.00
K11. Explain the principles of non contrast enhanced MRA techniques based on steady-state sequences	3	4	5	12	80.00
K12. Explain the principles and use of negative enteric contrast, positive enteric contrast and biphasic contrast medium for MRI of the bowel in MR Enterography.	5	4	3	12	80.00
S1. Set up abdomen RF coil according to vendor and Medical Physicist specifications	5	5	5	15	100.00

S2. Set up respiratory and cardiac triggering.	5	5	5	15	100.00
S3. Select body protocols for both cooperative and uncooperative patients	5	5	5	15	100.00
S4. Select scan protocols (TR / TE values) to maximize diagnostic effectiveness within breath hold capabilities of the patient	4	5	5	14	93.33
S5. Select the appropriate receive bandwidth in conjunction with fat suppression techniques to improve SNR and reduce chemical shift artefact	4	5	3	12	80.00
S6. Select/adjust b-values to maximize diagnostic effectiveness of DWI protocol according to the organ being investigated.	3	5	3	11	73.33
S7. Generate and analyse ADC maps	3	5	3	11	73.33
S8. Select/ adjust TI values to maximize the diagnostic effectiveness of non-contrast MRA	4	5	5	14	93.33
S9. Select the appropriate contrast medium for imaging the various organs/tissues in body imaging	4	4	4	12	80.00
S10. Perform subtraction of pre-contrast and post-contrast images to identify enhancing lesions	4	5	4	13	86.67
Competence IA3: Assumes responsibility for the planning and execution of Breast MRI. MRI guided biopsy of the breast is planned under supervision of breast specialist.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain physics aspects for breast MRI including magnetic field homogeneity across both breasts, adequate magnetic field gradients to permit fast GRE imaging and use of bilateral breast coil for prone positioning.	5	4	5	14	93.33
K2. Explain the different fat suppression techniques commonly used in breast imaging (STIR, frequency selective pulses, combined frequency selective and STIR, Dixon method).	5	4	5	14	93.33
K3. Explain subtraction techniques used during breast imaging	5	4	5	14	93.33
K4. Explain the technical considerations and imaging parameters for multiphase 3D GRE T1-weighted series acquired before and at repeated intervals after MR contrast-agent	4	4	5	13	86.67
K5. Explain the principles of high in-plane resolution (pixel sizes less than 1mm), high temporal resolution (1-3min)	4	5	4	13	86.67

with adequate SNR in order to differentiate between benign and malignant lesions.					
K6. Describe the physical properties of silicone relevant to MR.	5	5	5	15	100.00
K7. Explain water-suppressing and fat-nulling sequences for evaluation of breast implants and soft tissue extra-capsular silicone.	5	4	4	13	86.67
K8. Explain the principles underlying silicone-suppressing sequences	5	4	4	13	86.67
K9. Explain the relevance of optimized scan parameters in Fast SE sequences used specifically for breast implant imaging	4	4	5	13	86.67
K10. Explain the importance of local shimming	5	5	4	14	93.33
K11. Explain the use of time-enhancement (time-intensity) curves	2	4	4	10	66.67
K12. Explain respiratory, cardiac motion, non-uniform fat suppression, wrap around artefacts in breast imaging and how these could be minimised.	5	5	4	14	93.33
K13. Explain qualitatively why central lines of k-space are acquired at the time of highest concentration of contrast agent	5	3	4	12	80.00
K14. Explain the meaning of Maximum Intensity Projection (MIP) images	5	4	5	14	93.33
S1. Set up the breast coil	5	5	5	15	100.00
S2. Adjust the FOV and matrix to maximize in-plane resolution	5	5	5	15	100.00
S3. Perform shimming for local magnetic field inhomogeneity.	4	4	5	13	86.67
S4. Select centre frequency for water, fat and silicone from spectral peaks.	5	5	4	14	93.33
S5. Select the appropriate contrast medium for breast imaging	5	4	4	13	86.67
S6. Select imaging parameters that place the maximum contrast-weighting of the first post-contrast series at or near the time of peak contrast agent uptake.	4	5	3	12	80.00

S7. Perform subtraction of pre-contrast and post-contrast images to identify enhancing lesions in breast MRI	5	5	5	15	100.00
S8. Analyze time-enhancement (time-intensity) curves	2	4	3	9	60.00
S9. Produce and analyze Maximum Intensity Projection (MIP) images of subtracted images for vascular bed assessment.	4	5	4	13	86.67
Competence IA4: Assumes responsibility for the planning and execution of Musculoskeletal (MSK) MRI including MRI arthrography and Kinematic MRI (e.g., patellar tracking).	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the technical considerations (T1 relaxation times, chemical shift, SNR, fat saturation, RF deposition, RF coils) when using higher field strengths (1.5T vs 3.0T) for MSK.	4	4	5	13	86.67
K2. Explain use of phase array coils and parallel imaging in MSK.	5	5	5	15	100.00
K3. Explain the advantages and disadvantages of using intermediate TE when compared to long TE SE sequences in MSK.	3	5	3	11	73.33
K4. Explain the use of ultrashort TEs in the assessment of cortical bone, tendons and ligaments.	3	4	4	11	73.33
K5. Explain the physics underlying the magic-angle effect associated with intermediate TE spin echo sequences	3	4	2	9	60.00
K6. Explain methods that allow images to be obtained in the presence of the inhomogeniety caused by orthopaedic implants (Dixon-based methods, prepolarized MR imaging, view angle tilting).	3	4	2	9	60.00
K7. Discuss technical considerations for direct and indirect MR arthrography (T1 Fat saturation, artefact associated with intra-articular gadolinium).	4	5	4	13	86.67
K8. Discuss technical considerations for kinematic MRI in MKS (dynamic phase contrast sequences, single slice, spiral real-time sequences, open MR systems vs short bore MR systems).	2	4	2	8	53.33
K9. Explain current MR imaging techniques to assess morphologic status of cartilage including conventional SE and GRE, fast SE, isotropic 3D SE and GRE.	4	4	3	11	73.33
K10. Explain compositional assessment techniques include T2 mapping, delayed gadolinium-enhanced MR imaging	2	3	2	7	46.67

of cartilage (dGEMRIC), T1ρ imaging, sodium imaging, DWI and MR spectroscopy.					
S1. Select and connect dedicated phase-array coils appropriate to the MSK area under investigation	5	5	4	14	93.33
S2. Produce image contrast values to maximize the diagnostic effectiveness at 1.5T or 3.0T	3	5	3	11	73.33
S3. Select/ adjust the TE values for proton density imaging including those acquired with fat suppression	4	5	4	13	86.67
S4. Select / adjust for uTE to maximize image quality in the assessment of cortical bone, tendons and ligaments.	3	5	2	10	66.67
S5. Select/modify the scanning protocol in the presence of metallic orthopaedic implants.	5	5	4	14	93.33
S6. Select the best imaging plane to maximize diagnostic effectiveness	5	4	5	14	93.33
S7. Set up the scanner for kinematic assessment of joints	3	5	3	11	73.33
Competence IA5: Assumes responsibility for the planning and execution of MR Cholangiopancreatography (MRCP), MRI Liver, MRI Pancreas and MRI Liver Elastography	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the scan parameters of 2D and 3D single shot Fast SE sequence in generating MRCP images.	5	4	5	14	93.33
K2. Discuss the use of negative contrast with high manganese content in MRCP imaging	2	4	2	8	53.33
K3. Explain the underlying physics in using dual GRE sequences	4	5	4	13	86.67
K4. Explain the pharmacokinetics	3	3	2	8	53.33
K5. Explain how respiratory and pulsation artefacts can mimic pathology	5	5	4	14	93.33
K6. Explain when to use hepatocyte specific contrast medium and when to use extracellular contrast agents including bolus timing to achieve peak arterial enhancement	3	3	3	9	60.00
K7. Explain qualitative and quantitative techniques (signal intensity ratio, relaxometry) used to measure presence of iron in liver	2	3	3	8	53.33
K8. Explain the different qualitative and quantitative methods to assess fat deposition in the liver, e.g. chemical shift	3	4	2	9	60.00

imaging and MR spectroscopy.					
K9. Explain the basic principles of MR Elastography based on shear wave propagation	3	3	2	8	53.33
K10. Explain how elastograms are generated and analysed.	2	4	3	9	60.00
S1. Choose appropriate scan parameters for 2D and 3D single shot Fast SE sequence for generating MRCP images.	5	5	3	13	86.67
S2. Select/adjust TE values to maximize liver tissue contrast	3	5	5	13	86.67
S3. Apply respiratory gating or respiratory compensation to reduce motion artefacts	5	5	5	15	100.00
S4. Apply pre-saturation pulses to decrease flow motion artefact	4	5	5	14	93.33
S5. Select/adjust receive bandwidth and fat saturation techniques to reduce chemical shift artefact	5	5	4	14	93.33
S6. Select parallel imaging technique to maximize spatial resolution	4	5	4	13	86.67
S7. Perform subtraction of pre-contrast and post-contrast images to identify enhancing lesions	4	5	5	14	93.33
Competence IA6: Assumes responsibility for the planning and execution of MRI male pelvis including prostate and rectum	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the technical considerations (choice of coils, motion artefacts) when imaging the male pelvis.	5	5	5	15	100.00
K2. Explain the technical considerations for high resolution multiparametric sequences (T2W, DWI and DCE-MRI) when imaging the prostate and rectum	4	5	5	14	93.33
K3. Discuss qualitative and quantitative methods to analyse Dynamic Contrast Enhancement (DCE) data for enhancement pattern in prostate.	2	3	3	8	53.33
K4. Differentiate between methods for MR-guided prostate biopsy (transrectal interventional 'in-bore' MR; fusion biopsy with TRUS).	2	4	3	9	60.00
K5. Explain the relevance of T2-weighted Half-Fourier single-shot fast spin-echo (SSFSE) in imaging the rectum	4	4	3	11	73.33

S1. Set up an endorectal coil in conjunction with a phased array coil for imaging of the prostate; for other areas phased array coil.	2	5	4	11	73.33
S2. Select/modify the scanning parameters to achieve high resolution T2W sequences in 3 orthogonal planes for prostate and rectum	5	5	3	13	86.67
S3. Select asymmetric FOV to acquire fine matrix in conjunction with shorter scan time	5	5	4	14	93.33
S4. Select a range of b-values to maximize the diagnostic effectiveness of the DWI protocol in prostate and rectum imaging	2	5	4	11	73.33
S5. Select an adequate temporal resolution to achieve time intensity curves for prostate imaging	2	5	3	10	66.67
S6. Display and analyze coloured maps of DCE data superimposed on T2W images.	2	5	3	10	66.67
Competence IA7: Assumes responsibility for the planning and execution of MRI female pelvis including uterus, cervix, and ovaries.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain technical consideration (high resolution T2W / T1W FSE sequences; Dynamic T1W CM sequences) for female pelvis.	5	4	5	14	93.33
K2. Explain native imaging and MR angiography for Uterine Artery Embolization (UAE).	2	3	4	9	60.00
K3. Explain fast real-time imaging (single shots FSE; balanced SSp) for dynamic imaging in assessment of pelvic floor dysfunction.	4	3	4	11	73.33
K4. Discuss the use of endovaginal coils in obtaining high resolution images of urethra	5	5	5	15	100.00
S1. Place endovaginal coil to maximize image quality of the urethra	3	5	5	13	86.67
S2. Setup phased array in the imaging of the female pelvic organs	5	5	5	15	100.00
S3. Set up the patient and contrast media used during assessment of pelvic floor in order to reduce motion artefacts.	5	5	4	14	93.33
S4. Select/adjust flip angle, TR and TE values to maximize the image quality in T1W GRE sequence	4	5	4	13	86.67

S5. Select/modify the scanning parameters to achieve high resolution T2W sequences in 3 orthogonal planes for female pelvis	5	5	3	13	86.67
S6. Select/adjust the imaging planes for imaging of the uterus including dynamic contrast enhanced imaging of uterus for staging endometrial carcinoma	5	5	3	13	86.67
Competence IA8: Assumes responsibility for the planning and execution of Paediatric MRI.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the protocol parameters that are modified to optimize SNR (coil selection, voxel size, acquisition time,) for children	5	5	5	15	100.00
K2. Explain the scan parameters adjustments to optimize contrast for different spectrum of disease compared to adults.	3	5	5	13	86.67
K3. Explain fast imaging scans to reduce acquisition time in paediatric imaging	5	5	5	15	100.00
K4. Explain how respiratory motion artefacts could be reduced in paediatric imaging	5	5	5	15	100.00
K5. Explain the use of fluid sensitive sequences (T2W Fat sat; STIR, PD and 2DFFE) in paediatric protocols (Bare Bone protocol).	5	4	3	12	80.00
K6. Explain qualitatively rotating k-space acquisition techniques to reduce motion artefacts.	3	4	1	8	53.33
K7. Discuss how DWI acquisition needs to be modified in paediatric imaging.	4	5	5	14	93.33
S1. Select the ideal RF coil for paediatric imaging paying attention to SAR safety	5	5	5	15	100.00
S2. Select/adjust TR, TE values and voxel size to maximize image quality criteria in paediatric imaging	5	5	4	14	93.33
S3. Adjust the TI (inversion time) value in STIR to improve the Signal to Noise resolution	5	5	4	14	93.33
S4. Select a motion reducing strategy to improve image quality	5	5	4	14	93.33
S5. Select receive bandwith, number of excitations and phase encoding steps to maximize the acquisition time	5	5	3	13	86.67
S6. Select a range of b-values to maximize the diagnostic effectiveness of peadiatric imaging	3	5	3	11	73.33

Competence IA9: Shares responsibility for the planning and execution of MRI sequences requested for the assessment of change in tumour burden as a measure of treatment response or tumour progression.	Participants in favour				
	RG	RD	MP	Total	%
K1. Define tissue permeability.	3	4	3	10	66.67
K2. Explain how blood-brain barrier permeability can be estimated from temporal measurements of contrast agent concentration	4	3	3	10	66.67
K3. Discuss the clinical application of MR permeability imaging to tumour investigation and other disorders	3	4	5	12	80.00
K4. Explain the application of arterial spin labelling (ASL) to tumour blood flow	5	2	3	10	66.67
K5. Explain the application of MR Spectroscopy (MRS) as applied to tumour progression and treatment follow-up	4	4	2	10	66.67
K6. Explain the application of of Chemical Shift Imaging (CSI) as applied to tumour progression and treatment follow-up	4	4	2	10	66.67
S1. Select the appropriate TE to maximize the visibility of metabolites as applied to tumour progression and treatment follow-up	2	5	2	9	60.00
S2. Carry out system calibration prior to MR Spectroscopy (MRS) as applied to tumour progression and treatment follow-up	3	5	3	11	73.33
S3. Choose appropriate voxel position	4	5	4	13	86.67
S4. In CSI select the appropriate TE to maximize the characterization different regions of normal tissue and tumour	3	5	4	12	80.00
S5. Calculate metabolite ratios using the available software	3	5	3	11	73.33
S6. Select spin labelling duration time and prescribe labels to acquire pseudo continuous ASL images	2	5	2	9	60.00
S7. Carry out post-processing of spin labelling images (control and tag images) as per current recommended guidelines	4	5	2	11	73.33
Competence IA10: Shares responsibility for the planning and execution of MRI cardiac procedures under supervision	Participants in favour				

of a cardiac specialist	RG	RD	MP	Total	%
K1. Explain the MRI system components for high quality cardiac MRI (cardiac coil, ECG vector gating, high speed gradient coils)	5	5	4	14	93.33
K2. Explain respiratory compensation methods and cardiac synchronised fast and ultra-fast (single-shot) sequences.	5	5	5	15	100.00
K3. Explain FSE, double/triple inversion recovery for morphological (‘black-blood’) imaging	5	3	4	12	80.00
K4. Explain spoiled gradient echo and balanced steady state free precession (BSSFP) for functional dynamic (‘bright-blood’) imaging	5	3	4	12	80.00
K5. Explain qualitatively segmented k-space GRE acquisition (multiple shot imaging)	3	3	4	10	66.67
K6. Explain dynamic myocardial tagging with spatial modulation of magnetisation (SPAMM).	3	4	4	11	73.33
K7. Explain the use exogenous contrast agents to modify contrast (myocardial perfusion imaging using single shot technique with a fast (or turbo) spoiled gradient echo (FGE), balanced steady state free precession (bSSFP), or echo planar imaging (EPI)).	4	4	3	11	73.33
K8. Explain quantitative analysis of functional dynamic imaging.	4	3	3	10	66.67
K9. Explain T1 mapping and the various modified look-locker acquisitions (MOLLI).	3	3	2	8	53.33
K10. Explain the principles of viability imaging (late gadolinium enhancement).	5	4	4	13	86.67
S1. Set up cardiac coil	5	5	5	15	100.00
S2. Set up ECG triggering paying particular attention to ECG cable placement safety issues	5	5	5	15	100.00
S3. Select and plan the Magnetization-prepared fast GRE sequences for maximized diagnostic effectiveness of myocardial perfusion	4	5	4	13	86.67
S4. Select and adjust the TR and flip angle in GRE sequences to maximize CONTRAST between myocardium and blood pool.	4	5	4	13	86.67
S5. Perform shimming to acquire a full three-dimensional cine bSSFP dataset in a single breath hold.	3	4	5	12	80.00

S6. Select the optimal TI time to achieve complete signal nulling from normal myocardium during late gadolinium enhancement	4	5	4	13	86.67
S7. Select a pulse sequence scheme that allows for accurate in vivo T1 measurements and T1 mapping of myocardium with high spatial resolution and within a single breath-hold.	3	5	4	12	80.00
Competence IA11: Assumes responsibility for the planning and execution of vascular MRI.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the physics of flow, flow phenomena, and flow phenomena compensation.	5	5	5	15	100.00
K2. Explain conventional MRI vascular imaging techniques (Time of Flight, phase contrast MRA, Contrast enhanced MRA, black blood imaging, bright blood imaging).	5	5	5	15	100.00
K3. Explain the relevance of Gradient Moment Nulling and Magnetization Transfer in MRA techniques	3	3	3	9	60.00
S1. Select the appropriate MRA technique to maximize the diagnostic effectiveness	5	5	4	14	93.33
S2. Select/adjust Flip angles and TE values to maximize image quality of MRA	3	5	5	13	86.67
S3. Select / adjust VENC values to maximize diagnostic effectiveness of phase contrast MRA	5	5	4	14	93.33
S4. Place saturation bands to reduce signal from either arterial or venous flow	5	5	4	14	93.33
S5. Select the appropriate ramping technique in 3D TOF MRA to improve signal intensity	3	5	4	12	80.00
S6. Select Gradient Moment Nulling and Magnetization Transfer to increase the conspicuity of vessels	3	4	3	10	66.67
Competence IA12: Assumes responsibility for the planning and execution of MRI carried out under general anaesthesia.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the principles of the physiological monitoring instruments used by the anaesthetist.	5	3	5	13	86.67
S1. Evaluate the need for the use of specific ancillary equipment.	3	5	5	13	86.67

S2. Set up and use physiologic monitoring equipment as directed by anaesthetist.	5	5	5	15	100.00
Competence IA13: Assumes responsibility for the operation of MRI equipment at 3T.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the advantages and disadvantages of 3T MRI in terms of image quality criteria, device performance indicators, safety	5	5	5	15	100.00
K2. Explain the effects of higher magnetic field in relaxation effects, spin labeling, chemical shift at 3T	5	5	5	15	100.00
K3. Discuss compensatory measures to the effects of 3T on SNR, CNR and SAR levels	5	5	5	15	100.00
K4. Explain the principles of advanced neuro-imaging applications at 3T including MR Spectroscopy; fMRI; DWI, susceptibility weighted imaging; perfusion imaging; diffusion tensor imaging.	4	3	4	11	73.33
K5. Explain the principles of advanced abdominal imaging applications at 3T including chemical shift imaging.	5	4	3	12	80.00
K6. Explain the principles of advanced cardiovascular imaging applications at 3T.	3	3	5	11	73.33
K7. Explain the challenges in image quality criteria when considering breast and musculoskeletal MRI at 3T	5	5	5	15	100.00
S1. Select / adjust TR values in T1W sequences to improve SNR at 3T	5	5	5	15	100.00
S2. Select /adjust receive bandwidth to reduce the effects of chemical shift at 3T	5	5	4	14	93.33
S3. Keep a vigilant look on SAR values when adjusting scanning parameters (TR, Flip angle) at 3T	5	5	5	15	100.00
S4. Select / adjust TR/TE values to reduce acquisition time at 3T	4	5	4	13	86.67
S5. Select / adjust voxel dimension to increase spatial resolution without affecting acquisition time at 3T	5	5	5	15	100.00
S6. Select / adjust TE values to maximize chemical shift imaging in the abdomen at 3T	4	5	4	13	86.67
S7. In T2W sequences select techniques (RF cushioning, multichannel coils) to mitigate against RF shielding, standing wave artefacts and B1 inhomogeneity	4	4	4	12	80.00

S8. Select/adjust TI to allow adequate relaxation of longitudinal magnetization in cardiac LGE imaging at 3T	2	5	5	12	80.00
Competence IA14: Participates in oncology planning with MRI-PET fusion imaging.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the principles and aims of multimodality imaging; image co-registration; and longitudinal imaging	4	4	4	12	80.00
K2. Explain the principles of MRI techniques used for treatment planning and simulation in oncology	5	4	5	14	93.33
K3. Explain the impact of artifacts (e.g., tissue misclassification) and geometric distortions in oncology planning	4	4	5	13	86.67
K4. Demonstrate sufficient knowledge of oncology planning software to be an effective member of the planning team	4	3	3	10	66.67
S1. To set up the laser beams alignments necessary for PET-MRI fusion	5	4	5	14	93.33
S2. Use PET-MRI imaging software for oncology planning in partnership with the nuclear medicine radiographer	5	3	4	12	80.00
Competence IA15: Assumes responsibility for the MRI component of image acquisition in MRI-PET.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the principles and aims of multimodality imaging, image co-registration and longitudinal imaging	5	4	4	13	86.67
K2. Explain principles of MRI-based attenuation correction (segmentation-based AC and atlas-based AC)	2	3	3	8	53.33
K3. Explain the relevance of in-plane resolution when optimizing MRI protocols for MRI-PET.	4	4	4	12	80.00
K4. Explain the specific characteristics of MRI-PET imaging software	5	2	3	10	66.67
S1. Acquire MRI-PET images in partnership with the nuclear medicine radiographer	5	4	5	14	93.33
S2. Use MRI-PET software for MRI-PET in partnership with the nuclear medicine radiographer	4	4	4	12	80.00
Competence IA16: Assumes responsibility for the evaluation of patient compatibility with MRI procedure and imaging requirements	Participants in favour				
	RG	RD	MP	Total	%

K1. Same knowledge as for Safety and Risk Management (SRM) competences SRM1 and SRM2 below	5	5	5	15	100.00
K2. Explain patient compatibility issues within the context of MRI	5	5	5	15	100.00
S1. Same skills as for Safety and Risk Management (SRM) competences SRM1 and SRM2 below	5	5	5	15	100.00
S2. Take actions to modify the MRI procedure to ensure patient compatibility	5	5	5	15	100.00
Competence IA17: Assumes responsibility for consulting with other MRI stakeholders as necessary on issues related to the MRI pathway including flagging of incidental findings to Radiologist and QA abnormal results to Medical Physicist.	Participants in favour				
	RG	RD	MP	Total	%
K1. Define relevant MRI device performance (including safety related) indicators used in pre-scan QC constancy testing as agreed with the Medical Physicist; state warning and acceptability limits.	4	5	4	13	86.67
K2. Define relevant post-scan physics image quality and safety criteria as agreed with the Medical Physicist; describe their method of measurement and state warning and acceptability limits.	3	5	5	13	86.67
K3. Understand any specific QA requirements of specific protocols and/or patient population	4	5	4	13	86.67
K4. Discuss the procedure for escalating quality issues to the Medical Physicist and manufacturer/service provider, and how this is followed up.	5	5	4	14	93.33
S1. Evaluate results of device pre-scan QC (including safety related) constancy testing as agreed with the Medical Physicist; flag values beyond warning and acceptability limits	4	5	5	14	93.33
S2. Evaluate results of post-scan QC physics image quality and safety criteria assessment as agreed with the Medical Physicist; flag values beyond warning and acceptability limits	3	5	5	13	86.67
S3. Correct common faults through appropriate procedure, report other faults to Medical Physicist	4	5	5	14	93.33
Competence IA18: Applies appropriateness criteria for MRI referrals following discussion with consultant Radiologist.	Participants in favour				
	RG	RD	MP	Total	%
No additional Physics knowledge or skills. Do you agree?'	5	4	5	14	93.33

Competence E1: Assumes responsibility for providing information to patients before scanning and obtain informed consent.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the regular physics-related information that should be provided to patients (particularly sequence instructions and patient safety related) and rationale for providing said information.	5	5	5	15	100.00
S1. Communicate regular physics-related information to patients and evaluate the effectiveness of such communication.	4	5	5	14	93.33
Competence E2: Participates in providing information on the diagnostic utility of different MRI techniques and associated pulse sequences in the various areas of MRI to healthcare professionals and specialty trainees.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain regular physics-related information that should be provided to the various healthcare professionals and specialty trainees (particularly strengths and limitations of the various studies, sequence instructions, patient and occupational safety related) and rationale for providing said information.	3	4	5	12	80.00
S1. Communicate regular physics-related information to healthcare professionals and specialty trainees and evaluate the effectiveness of the communication.	4	4	5	13	86.67
Competence E4: Participates in the provision of information about the strengths, limitations and safety of MRI to other stakeholders including the general public	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain regular physics-related information that should be provided to other stakeholders including the general public (particularly strengths and limitations of the various studies, patient and occupational safety related) and rationale for providing said information.	4	4	5	13	86.67
S1. Communicate to other stakeholders including the general public regular physics-related information (particularly strengths and limitations of the various studies, patient and occupational safety related) that should be provided to them and evaluate the effectiveness of the communication.	3	4	5	12	80.00
Competence E5: Participates in the development of quality assured MRI courses to MD and Non-MD healthcare professionals.	Participants in favour				
	RG	RD	MP	Total	%

	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of regular physics related terminology to be able to liaise with Medical Physicists in the development of quality assured MRI courses to MD and Non-MD healthcare professionals	5	5	4	14	93.33
S1. Use regular physics terminology sufficiently well to be able to liaise with Medical Physicists in the development of quality assured MRI courses to MD and Non-MD healthcare professionals	5	5	4	14	93.33
Competence E6: Assumes responsibility for mentoring student radiographers, and for participation in the education and training of student Medical Physicists and trainee Radiologists during their clinical placements	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of regular physics related terminology to liaise with trainee Medical Physicists and trainee Radiologists during their clinical placements	5	5	4	14	93.33
S1. Use regular physics terminology sufficiently well so as to be able to liaise with trainee Medical Physicists and trainee Radiologists during their clinical placements	5	5	4	14	93.33
Competence QA1: Participates in the establishment of objective quality criteria for the evaluation and monitoring of service quality at all stages of the care pathway.	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics-related terminology to be able to liaise with Medical Physicists in the establishment of acceptable values for pre-scan device performance indicators and post-scan image quality and safety criteria.	2	5	5	12	80.00
S1. Liaise effectively with Medical Physicists in the establishment of acceptable values for pre-scan device performance indicators and post-scan image quality and safety criteria.	3	5	4	12	80.00
Competence QA2: Assumes responsibility for preparing and documenting a controlled radiographer's technical report for each scan. (Technical report would include information about patient assessment; image quality; SAR levels; clinical indications; sequence optimization, incidental findings or patient assessment).	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the importance of pre-scan device QC constancy testing for a quality service	3	5	5	13	86.67
K2. Explain the bioeffects of static and dynamic electromagnetic fields on patients	4	5	4	13	86.67

K3. Explain the meaning of SAR and it's relevance to MRI safety	5	5	5	15	100.00
K4. Explain the need for measuring patient mass prior to scanning and its input into the scanner	5	5	5	15	100.00
K5. Define relevant device MRI device performance (including safety related) indicators used in pre-scan QC constancy testing as agreed with the Medical Physicist; describe their method of measurement and state warning and acceptability limits.	4	5	4	13	86.67
K6. Explain the physics underlying the QC test objects used in constancy testing.	4	3	4	11	73.33
K7. Explain the importance of post-scan assessment of physics image quality and safety criteria for the MRI pathway	3	5	4	12	80.00
K8. Define relevant post-scan physics image quality and safety criteria as agreed with the Medical Physicist; describe their method of measurement and state warning and acceptability limits.	3	5	4	12	80.00
S1. Carry out ongoing device pre-scan QC constancy (including safety related) testing as agreed with the Medical Physicist; evaluate results and flag values beyond warning and acceptability limits	4	5	4	13	86.67
S2. Check that patient pre-scan safety screening form is properly filled in and signed	5	5	5	15	100.00
S3. Record patient mass and SAR level, confirm within acceptable level	3	5	5	13	86.67
S4. Carry out ongoing device post-scan assessment of physics image quality and safety criteria as agreed with the Medical Physicist; evaluate results and flag values beyond warning and acceptability limits	3	4	4	11	73.33
S5. Correct common faults through appropriate procedure, report other faults to Medical Physicist	4	5	5	14	93.33
S6. Ensure all physics parameters are recorded in an appropriate manner in the technical report	5	4	5	14	93.33
S7. Assess the quality of own technical report	5	4	4	13	86.67
Competence QA3: Participates in the development, distribution, collection, analysis and reporting of patient satisfaction surveys.	Participants in favour				
	RG	RD	MP	Total	%
No additional Physics knowledge or skills. Do you agree?	4	4	5	13	86.67

Competence QA4: Participates in multi professional group in auditing of the MRI Care Pathway against national and local quality benchmarks (e.g., appropriateness of referrals, patient satisfaction, radiographer technical report)	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics-related terminology to be able to liaise with Medical Physicists in the in the auditing of the MRI Care Pathway against national and local quality benchmarks	4	5	5	14	93.33
S1. Liaise with Medical Physicists in the in the auditing of the MRI Care Pathway against national and local quality benchmarks	3	5	5	13	86.67
S2. Cooperate with Medical Physicists in internal audits with respect to physics-related national and local quality benchmarks	3	5	4	12	80.00
S3. Cooperate with Medical Physicists in with respect to physics-related national and local quality benchmarks	4	5	4	13	86.67
Competence QA5: Participates in multi professional group in the auditing of the effectiveness of the MRI service against target patient management outcomes.	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics-related terminology to be able to liaise with Medical Physicists in the in auditing of the effectiveness of the service against target patient management outcomes.	2	4	5	11	73.33
S1. Cooperate with Medical Physicists in auditing of physics-related service effectiveness aspects against target patient management outcomes.	2	4	5	11	73.33
Competence SRM1: Assumes responsibility for risk assessment and the provision for the physical and psychological needs of patients before, during and after the scan	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain the risks within the MRI environment to patients, staff and visitors	5	5	5	15	100.00
K2. Explain the meaning of SAR and its relevance to patient risk	5	5	5	15	100.00
K3. Discuss the effects of static and gradient magnetic fields on the human body including the unborn child	4	5	5	14	93.33
K4. Explain what happens when RF (radio frequency) is pulsed into the body.	5	5	5	15	100.00

K5. Explain and compare safety concerns associated with both external and internal (to the magnet) areas of the magnetic field.	5	5	5	15	100.00
K6. Distinguish between MR safe, unsafe and conditional items and devices.	5	5	5	15	100.00
K7. List and briefly explain the types of medically implanted metal objects that might be found in a patient's body and can be a potential hazard when the patient is placed in a magnetic field.	5	5	5	15	100.00
K8. Explain the procedure for determining if a specific medical device, such as a surgical clip, is a potential hazard when the patient is placed in a magnetic field.	5	5	5	15	100.00
K9. Identify the conditions that can produce skin burns during an MRI acquisition and explain the steps to take to prevent them.	5	5	5	15	100.00
K10. Explain the hazards associated with acoustic noise.	5	5	5	15	100.00
S1. Carry out risk assessment and take measures to eliminate / reduce risks.	5	5	4	14	93.33
S2. Liaise with Medical Physicists to ensure that any items/devices brought into the MR room are checked for MR safe/unsafe/conditional status and their use or otherwise stipulated within the local Code of Practice.	5	5	5	15	100.00
S3. Carry out pre-scan patient safety screening, ensure screening form is properly filled in and signed, patient mass measured and inputted to system.	5	5	5	15	100.00
S4. Collaborate with Medical Physicists in the setting up of a local Code of Practice	3	5	5	13	86.67
S5. Adhere to national, European and international legislation/recommendations regarding the safe use of MRI for patients, staff and visitors with respect to all physical agents within the MR environment	5	5	5	15	100.00
Competence SRM2: Assumes responsibility for the application of standard safety operating procedures (SOP) in maintaining a working environment safe from hazards that could arise from chemical, physical and biological agents.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain physics related issues within local SOPs (including any associated Codes of Practice)	5	5	5	15	100.00
K2. Explain the relevance of the screening procedure required for an individual and patient prior to being allowed into	5	5	5	15	100.00

to the MRI environment or to undergo an MRI examination.					
K3. Explain national, European & international legislation/recommendations regarding safe use of MRI for patients, staff, visitors	5	5	5	15	100.00
K4. Explain when and how to quench the magnet and handle other emergencies in the MR environment.	5	5	5	15	100.00
K5. Explain completely the procedures to be followed to prevent hazardous metal objects to be brought into the magnetic field area.	5	5	5	15	100.00
S1. Adhere to physics related issues within local SOPs (including any associated Codes of Practice)	5	5	5	15	100.00
Competence SUM1: Participates in the delivery of information on and application of MRI legislation.	Participants in favour				
	RG	RD	MP	Total	%
Same additional physics knowledge and skills as for competences SRM1 and SRM2	3	5	5	13	86.67
Competence SUM2: Participates in the update of local MRI departmental regulations and procedures to any EU legislation and documentation.	Participants in favour				
	RG	RD	MP	Total	%
Same additional physics knowledge and skills as for competences SRM1 and SRM2	4	5	5	14	93.33
Competence SUM3: Participates in the use of referral guidelines in order to prioritize accessibility to services.	Participants in favour				
	RG	RD	MP	Total	%
K1. Explain physics-related issues included in European/National/local referral guidelines	3	4	5	12	80.00
S1. Liaise with Medical Physicists in the application of physics-related issues included in European/National/local referral guidelines	4	4	5	13	86.67
Competence SUM4: Participates in the development of Standard Operating Procedures (e.g., regulating non-MD referrals if these are implemented).	Participants in favour				
	RG	RD	MP	Total	%

K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in the in the development of Standard Operating Procedures	3	5	5	13	86.67
S1. Liaise with Medical Physicists in the development of Standard Operating Procedures	4	5	5	14	93.33
Competence FM1: Assumes responsibility for the provision of on call services on a 24/7 basis.	Participants in favour				
	RG	RD	MP	Total	%
No additional Physics knowledge or skills. Do you agree?	4	5	5	14	93.33
Competence FM2: Assumes responsibility for the offer of advice on the management of resources including waiting list initiatives.	Participants in favour				
	RG	RD	MP	Total	%
No additional Physics knowledge or skills. Do you agree?	4	4	5	13	86.67
Competence FM3: Participates in a multi professional group in the development of referral guidelines and the certification of MRI referrers in order to grant referring privileges.	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with physicists in the in the development of referral guidelines and learning outcomes for referrers	2	3	4	9	60.00
S1. Liaise with Medical Physicists in the in the development of referral guidelines and learning outcomes for referrers	2	4	4	10	66.67
Competence FM4: Participates in activities for ensuring that quality and safety of MRI services are ISO assured.	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in ISO certification applications	4	4	4	12	80.00
S1. Liaise with Medical Physicists in ISO certification applications	4	5	4	13	86.67

Competence FM5: Participates in the procurement of MRI scanners and associated medical devices.	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in the procurement of MRI scanners and associated medical devices.	3	3	4	10	66.67
S1. Liaise with Medical Physicists in the procurement of MRI scanners and associated medical devices.	3	4	4	11	73.33

Competence R1: Takes responsibility for independent research or with other healthcare professionals	Participants in favour				
	RG	RD	MP	Total	%
K1. Demonstrate sufficient understanding of physics terminology to be able to liaise with Medical Physicists in MRI research	3	4	4	11	73.33
K2. Explain the three IEC operating modes (normal, first-level and second-level controlled) and relevance to MRI research	5	4	4	13	86.67
K3. Understand the importance of adhering to agreed scanning protocols in clinical research trials	5	5	5	15	100.00
S1. Liaise with Medical Physicists in MRI research	3	5	4	12	80.00

Appendix H – Example SPSS printout of Fischer's Exact Test

IA5K10 Required * PROF1 Profession

Crosstab

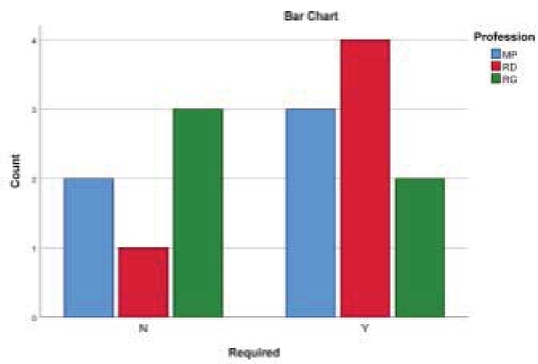
			PROF1 Profession			
			MP	RD	RG	Total
IA5K10 Required	N	Count	2	1	3	6
		% within PROF1 Profession	40.0%	20.0%	60.0%	40.0%
	Y	Count	3	4	2	9
		% within PROF1 Profession	60.0%	80.0%	40.0%	60.0%
Total		Count	5	5	5	15
		% within PROF1 Profession	100.0%	100.0%	100.0%	100.0%

Page

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	1.667[a]	2	.435	.800
Likelihood Ratio	1.726	2	.422	.800
Fisher's Exact Test	1.666			.800
N of Valid Cases	15			

a. 6 cells (100.0%) have expected count less than 5. The minimum expected count is 2.00.



IA5K10 - Explain how elastograms are generated and analysed

IA5S2 Required * PROF1 Profession

Crosstab

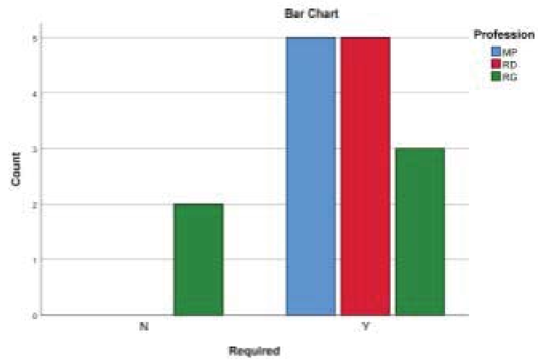
			PROF1 Profession			
			MP	RD	RG	Total
IA5S2 Required	N	Count	0	0	2	2
		% within PROF1 Profession	0.0%	0.0%	40.0%	13.3%
	Y	Count	5	5	3	13
		% within PROF1 Profession	100.0%	100.0%	60.0%	86.7%
Total		Count	5	5	5	15
		% within PROF1 Profession	100.0%	100.0%	100.0%	100.0%

Page

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	4.615[a]	2	.099	.286
Likelihood Ratio	5.050	2	.080	.286
Fisher's Exact Test	3.223			.286
N of Valid Cases	15			

a. 6 cells (100.0%) have expected count less than 5. The minimum expected count is .67.



IA5S2 - Select/adjust TE values to maximize liver tissue contrast

E4S1 Required * PROF1 Profession

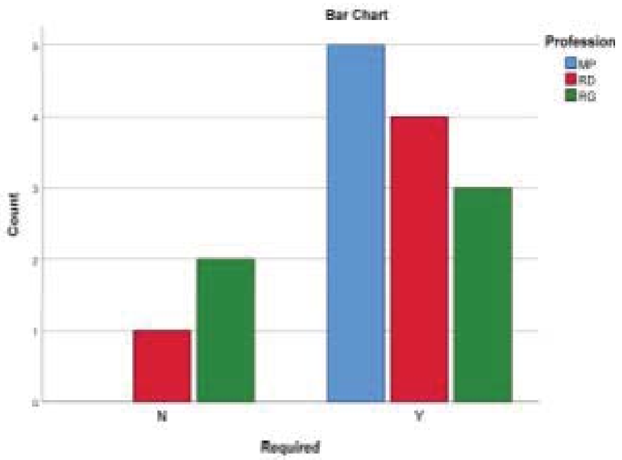
Crosstab

			PROF1 Profession			
			MP	RD	RG	Total
E4S1 Required	N	Count	0	1	2	3
		% within PROF1 Profession	0.0%	20.0%	40.0%	20.0%
	Y	Count	5	4	3	12
		% within PROF1 Profession	100.0%	80.0%	60.0%	80.0%
Total		Count	5	5	5	15
		% within PROF1 Profession	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	2.500[a]	2	.287	.725
Likelihood Ratio	3.278	2	.194	.725
Fisher's Exact Test	2.286			.725
N of Valid Cases	15			

a. 6 cells (100.0%) have expected count less than 5. The minimum expected count is 1.00.



E4S1 - Communicate to other stakeholders including the general public regular physics-related information (particularly strengths and limitations of the various studies, patient and occupational safety related) that should be provided to them and evaluate the effectiveness of the communication.

Appendix I - Copies of main publications and the award winning presentation arising from or related to this research.

The presentation titled 'Validation of a competence profile for magnetic resonance radiographers using a formal research process' was awarded 'Best Scientific Paper Presentation' within the topic Radiographers at the European Congress of radiology, held in Vienna between the 2nd and 6th March 2017.

Radiography xxx (2011) 1–5

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level

Joseph Castillo [a,*], Carmel J. Caruana [b], David Wainwright [c]

[a] Medical Imaging Department, Mater Dei Hospital, Msida, Malta
[b] Biomedical Physics, Faculty of Health Sciences, University of Malta, Msida, Malta
[c] Work, Health and Wellbeing Research Group, University of Bath, Claverton Down, Bath BA2 7AY, UK

A R T I C L E   I N F O

Article history:
Received 19 November 2010
Received in revised form
22 December 2010
Accepted 28 December 2010
Available online xxx

Keywords:
Competence
Competency
Curriculum development
Learning outcomes
Qualification frameworks
Radiography competences

A B S T R A C T

The Bologna process has made the qualifications framework of the European Higher Educational Area based on three cycles and on learning outcomes central to curriculum development in higher education in Europe. The Tuning Educational Structures in Europe project recommended that learning outcomes be expressed in terms of competences. The expression of educational programme learning outcomes as inventories of competences has since become the norm at the European level. However, the more recent European Qualifications Framework for lifelong learning utilises a tripartite set of categories of learning outcomes, namely, knowledge, skills and competence. In addition, the definition of competence used though overlapping with that used by Tuning, is however not identical. This article reviews and discusses the changing definition of the concept of competence and changes in categorisation of learning outcomes in Europe and their potential impact on curriculum development in radiography at the European level. It is proposed that the shift in the definition of competence and in the categorisation of learning outcomes should be taken into account in the formulation of new European curricula or the updating of present ones so that they may reference in a more direct manner to the levels of the European Qualifications Framework.

Introduction

The rapid advances in technology, shortage of radiologists, changes in healthcare policies and continuous professional development (CPD) requirements have had an impact on radiography education in most countries where the profession is sufficiently well developed.[1–9] In addition, in Europe, curriculum developers are expected to structure educational programmes so as to facilitate student and worker mobility. A prerequisite for all this would be the development of qualification and curricular frameworks based on European recommendations. European thematic networks have aligned their curriculum development with the recommendations of the European Higher Education Area (EHEA) qualifications framework (QF-EHEA) which is based on three levels (called 'cycles') and on agreed learning outcomes expressed as competences as recommended by the Tuning Educational Structures in Europe project.[10–12] However, the more recent European Qualifications Framework (EQF) for lifelong learning utilises a tripartite set of categories of learning outcomes, namely, knowledge, skills and competence. In addition, the definition of competence used in the EQF though very much overlapping with that used by Tuning is not identical. This article reviews the changes in the definition of the concept of competence and the categorisation of learning outcomes in Europe and their potential impact on the design of curriculum documents in higher education (HE) at the European level. The authors put forward recommendations for radiography curriculum developers.

Materials and methods

Information was searched for in the English language databases Medline, Web of Knowledge, Embase and Cinahl using the key words: 'learning outcomes', 'competence', 'radiography education', 'European higher education area', 'Bologna process', and 'qualifications frameworks'. Important sources of information regarding European recommendations were the official websites for education and training of the European Commission,[13] the Bologna Process[14] and Tuning.[15]

* Corresponding author. Tel.: +35621667656.
E-mail address: josecast@go.net.mt (J. Castillo).

1078-8174/$ – see front matter © 2011 The College of Radiographers. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.radi.2010.12.008

The concept of competence: variable definition and terminology

The concept of competence is derived from the Latin *competens*, which means capable or qualified.[16] White[17] is credited with having introduced the term to describe those personality characteristics associated with superior performance and high motivation. McClelland[18] followed this approach and developed tests to predict competence as opposed to intelligence. Since then several definitions and approaches to the concept of competence have been proposed and there is a general lack of consensus over the meaning and use of the term.[19–22] To add to the ambiguity, articles in the educational literature present two spellings of the word, namely, 'competence' and 'competency' offering the same meaning to each with their respective plurals 'competences' and 'competencies' readily interchangeable. The first form of the word is in general used in the EHEA and Tuning documentation and the second in documentation from the US, Canada, Australia and New Zealand.[20] Some authors and organisations from the professional literature propose a distinction between 'competence' and 'competency'. For example, the Chartered Institute of Personnel and Development (UK) offers the following distinction[23]:

> *"Competency is now generally defined as the behaviours that employees must have, or must acquire, to input into a situation in order to achieve high levels of performance, while competence relates to a system of minimum standards or is demonstrated by performance and outputs"*

Woodruffe[24] provides a similar distinction:

> *"A competency is the set of behaviour patterns that the incumbent needs to bring to a position in order to perform its tasks and functions with competence"*

The inference here is that 'competency' is a level of behavioural excellence to aspire to, whilst 'competence' is simply a statement of minimum observable performance which is considered acceptable.

Rowe[25] makes a distinction between behaviours that are cognitively based and those that reflect personal values. In the cognitive category Rowe includes problem solving, decision-making, strategic thinking, and working with information whilst personal values include honesty, integrity, commitment and courage. Delamere le Deist and Winterton suggested an over-arching framework in which cognitive, functional, social and meta-competences are combined and viewed in holistic terms so that a combination of competences is something more than the sum of the individual competences.[21,26]

In Europe, the various definitions of competence found in the research literature and other educational documents from UK, France and Germany were used by the Bologna Working Group in Europe to suggest that competence includes:

(i) cognitive competence involving the use of theory and concepts, as well as informal tacit knowledge gained experientially,
(ii) functional competence (skills or know-how) referring to those activities that a person should be able to do when functioning in a given area of work, learning or social activity,
(iii) personal competence involving knowing how to conduct oneself in a specific situation, and
(iv) ethical competence involving the possession of certain personal and professional values.[10]

In a later document leading to the EQF recommendations, the terminology was simplified: 'cognitive competence' was termed 'knowledge', functional competence was termed 'skills' and personal and ethical competences were combined into a single category termed 'wider competences'. The wider competences included autonomy and responsibility, learning competence, communication and social competence and professional and vocational competence.[27] However in the final EQF recommendations the term 'wider competence' was dropped in favour of the simpler term 'competence'. The definition of competence in the EQF places emphasis on the terms 'responsibility' and 'autonomy' which reflects the importance of these concepts in work and study situations in which practitioners assume responsibility in an autonomous manner for their professional practice and also for their own learning.[28–30]

Practical approaches to competence

Gonczi[31] describes three practical approaches to competence. The first approach is referred to as task-based, functional or behaviourist where tasks are broken down into discrete behaviours that can be observed and assessed. In this way, the task becomes synonymous with the competence and is usually defined as, something a person should be able to do.[32] Its focus is more on objectively observable performance than on knowledge and it is concerned more with what people can demonstrate rather than with what they know.[33] This approach which is favoured by employers[19,21] has been criticised by health professions educators as being too reductionist, ignores the complexity of performing in real world situations and reduces the role of professional judgement in quality performance.[34] In addition, there is a concern that the humanistic aspects of care such as empathy will be eclipsed by the strictly technical aspects of healthcare which are easier to observe, demonstrate and assess.[35] The second approach refers to *generic* competences and concentrates on psychological and personality attributes of the practitioner that are crucial to effective performance. Generic competences such as critical thinking and problem-solving skills are transferable to different situations and professional work. However, doubts have been raised as to whether certain generic competences can be assessed effectively.[36] The third approach is a marriage between the functionalist and generic approaches applied to the context in which they are employed. Thus, complex combinations of knowledge, skills, values and attitudes are utilised to understand particular situations in which professionals may find themselves. This holistic view shifts the emphasis from specific observable tasks towards the purpose of the work or educational activity.[37,38] This outlook has been adopted by many radiography institutions where the assessment of radiography competences is designed to encompass all the above facets of competence as students progress through their studies.[39–42]

The European Higher Education Area Qualifications Framework (QF-EHEA)

The Bologna process seeks to create a European Higher Education Area (EHEA), harmonise European qualifications, foster the mobility of workers and students, the employability of graduates and assist the future development of Europe. Amongst the central features of the process is the structuring of higher educational qualifications based on three levels called 'cycles' (1st cycle Bachelor, 2nd cycle Masters and 3rd cycle Doctorate). The 'Tuning Educational Structures in Europe' programme is a university driven project, which aims to offer a concrete approach to implementing the Bologna agreement at the HE level and in particular subject areas such as Radiography. Tuning requires educational institutions to promote student-centred curriculum development based on agreed cycle learning outcomes expressed in terms of competences.[12] Although learning outcomes are formulated by staff these should be designed from the point of view of the student. It is indeed this feature that distinguishes learning outcomes from

Please cite this article in press as: Castillo J, et al., The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level, Radiography (2011), doi:10.1016/j.radi.2010.12.008

Table 1
The learning outcome descriptors for levels 6–8 of the European Qualification Framework.

	Knowledge In the context of EQF, knowledge is described as theoretical and/or factual	*Skills* In the context of EQF, skills are described as cognitive(involving the use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments	*Competence* In the context of EQF, competence is described in terms of responsibility and autonomy
Level 6 (e.g., first cycle of the QF-EHEA, Bachelor)	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups
Level 7 (e.g., second cycle of the QF-EHEA, Master)	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research; critical awareness of knowledge issues in a field and at the interface between different fields	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different field	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
Level 8 (e.g., third cycle of the QF-EHEA, Doctorate)	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

conventional teaching objectives which are written from the point of view of the teaching staff. Learning outcomes are to be acquired by the student (this is implied by the word 'learning' in 'learning outcome') and their acquisition by the student facilitated by the academic/clinical staff. The EQ-EHEA recognises only one type of learning outcome which is 'competence'. This explains why in Tuning documents 'learning outcomes' and 'competences' are often seen as synonymous. These competences are to be determined through the involvement of all stakeholders. Competence is defined by Tuning as "a dynamic concept that integrates knowledge, skills, abilities, values and attitudes, the development of which enables the learner to perform effectively, to be able to recognise and respond to change and to treat service users appropriately".[43] This definition indicates that the project leaders were aiming at the holistic approach to competence described by Gonczi.[37] The Tuning leaders proposed that competences be classified in two categories namely Generic and Subject Specific. Generic competences are defined by Tuning as those skills which are transferable across professions and which are considered to be particularly important to employability and citizenship whilst subject specific competences are specific to particular professions.[12] The Generic competences are further subdivided into three types namely instrumental, interpersonal and systemic whereas the Subject Specific competences can be divided into subcategories as decided by the different professions.

To address the problem of variability of radiography education in Europe and its impact on mobility the Higher Education Network for Radiography in Europe (HENRE)[44] has published an inventory of agreed Generic and Subject Specific competences for the first cycle of radiography (diagnostic and therapy) education.[43] HENRE did not develop any Generic or Subject Specific competences for the second and third cycles. However, Caruana and Plasek,[45] did develop inventories for the imaging physics component of radiography education (including inventories for the second and third cycle) in conjunction with HENRE.

The European Qualification Framework for lifelong learning

In 2006, the European Commission launched the European Qualifications Framework for lifelong learning.[11] The EQF is organised into eight levels that span the whole spectrum of education from basic to doctoral level.[46] The EQF builds on the successful policy goals of the EHEA, such as the consistency in the design of qualifications and extends it to all levels of education. In the EQF the first cycle of the EHEA (Bachelor) is classified at level 6, the second cycle (Master) at level 7 whilst the third cycle (Doctorate) is at level 8. It is hence important to note that it is possible to develop programmes which are compatible with both qualification frameworks. It should be noted that that HE programmes are only one means of reaching levels 6–8 and the EQF recognises (in the spirit of lifelong learning) that these levels can also be reached through informal and non-formal learning. By 2012 each EU member state is required to develop its own national qualification framework (NQF) in accordance with national legislation and practice and reference it to the EQF. Three countries (Malta, Ireland and UK) have referenced their NQF to the EQF.[47–51]

The EQF recognises three types of learning outcomes for each level namely knowledge, skill and competence learning outcomes. This is in contrast to the single category 'competences' of the QF-EHEA.[52] In the EQF, knowledge is defined as "*The outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual*"; skill is defined as "*the ability to apply knowledge and use know-how to complete tasks*

Please cite this article in press as: Castillo J, et al., The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level, Radiography (2011), doi:10.1016/j.radi.2010.12.008

and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments)"; competence is defined as *"the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the EQF, competence is described in terms of responsibility and autonomy"*. Table 1 shows the descriptors for the knowledge, skills and competence learning outcomes at each of levels 6–8.

Consequences of the adoption of the EQF for radiography education

The major significance of the EQF is that finally the educational community in Europe has a single set of agreed definitions and categorisation of learning outcomes to use in curriculum development at the European level (and the national level if so desired). This will go a long way towards reducing the uncertainty arising from the confusing plurality of definitions and approaches to competence to be found in the literature. In addition, the categorisation of learning outcomes into knowledge, skills and competence means that all of these categories of learning outcomes will be given their due importance. On the other hand it does imply that European curricular documents such as the HENRE Tuning Template for Radiography[53] and those of Caruana and Plasek[45] which are based solely on competences need to be partially rewritten so that they may reference in a more direct manner to the knowledge-skills-competence approach of the EQF. Learning outcomes of programmes such as the European Masters Programme in Medical Imaging (EMPIMI) project (which does refer to the EQF in its documentation)[54] will also need to be partially re-formulated.

One of the aims of the EQF is to bridge the gap between vocational education & training (VET) and HE.[55,56] Since not all European countries require radiographers to be qualified at HE level such a link would help bring Radiography in Europe into an all graduate profession. Through use of the EQF level descriptors, radiography curriculum developers in such states can develop link programmes from level 5 (VET) to level 6 (HE), thus enabling learners to make the transition from VET to HE. This can be achieved partially through recognition of the non-formal and informal learning which candidates would have acquired through experiential learning and CPD activities. Indeed, a detailed European profile of the radiography profession based on the EQF would make the recognition of non-formal and informal learning much easier. The general issue of transition from VET to HE requires research if present difficulties are to be overcome.[51,56]

The adoption of a European general radiography curriculum based on the EQF by the radiography profession can also facilitate the recognition of cross-border radiography qualifications on the basis of "coordination of minimum training conditions" as recommended by European Directive 2005/36/EC.[57] Paragraph 29 of the preamble to the directive states that: "Where a national and European-level professional organisation or association for a regulated profession makes a reasoned request for specific provisions for the recognition of qualifications on the basis of coordination of minimum training conditions, the Commission shall assess the appropriateness of adopting a proposal for the amendment of this Directive".

Conclusion and recommendations

The plethora of definitions attributed to the concept of competence and the various classifications of learning outcomes have in the past created difficulties for curriculum developers. The EC recommendations contained in the EQF for lifelong learning have helped to reduce the ambiguity. Curriculum developers can use the EQF recommendations to create robust curricular documents, which would facilitate mobility for students and professionals across Europe. It is suggested that:

- A detailed competence profile for European radiography be developed which is referenced directly to EQF levels and which would help bridge the gap between VET and HE in states where radiography education is not yet totally HE based.
- The learning outcomes contained within the HENRE Tuning Template for undergraduate radiography and those of the EMPIMI Master's programme are partially rewritten to reflect the knowledge, skills and competence approach of the EQF and the modified definition of competence formulated by the EQF.

References

1. Brealey SD, King DG, Hahn S, Crowe M, Williams P, Rutter P, et al. Radiographers and radiologists reporting plain radiograph requests from accident and emergency and general practice. *Clinical Radiology* 2005;**60**(6):710–7.
2. Smith T, Yielder J, Ajibulu O, Caruana E. Progress towards advanced practice roles in Australia, New Zealand and the Western Pacific. *Radiography* 2008;**14** (Suppl. 1):e20–3.
3. Smith TN, Baird M. Radiographers' role in radiological reporting: a model to support future demand. *Medical Journal of Australia* 2007;**186**(12):629–31.
4. Cowling C. A global overview of the changing roles of radiographers. *Radiography* 2008;**14**(Suppl. 1):e28–32.
5. The Society of Radiographers. *Research and the Radiography Profession. A strategy and five year plan*. Available from: http://www.sor.org/public/pdf/research/strat_fiveyr.pdf; 2005 [cited 2010 22nd December].
6. Forsyth LJ, Robertson EM. Radiologist perceptions of radiographer role development in Scotland. *Radiography* 2007;**13**(1):51–5.
7. Brealey S, King DG, Hahn S, Godfrey C, Crowe MTI, Bloor K, et al. The costs and effects of introducing selectively trained radiographers to an A&E reporting service: a retrospective controlled before and after study. *British Journal of Radiology* 2005;**78**(930):499–505.
8. Jensch S, van Gelder RE, Florie J, Thomassen-De Graaf MA, Lobe JV, Bossuyt PMM, et al. Performance of radiographers in the evaluation of CT colonographic images. *American Journal of Roentgenology* 2007;**188** (3):W249–55.
9. Larsson W, Aspelin P, Bergquist M, Hillergård K, Jacobsson B, Lindsköld L, et al. The effects of PACS on radiographer's work practice. *Radiography* 2007;**13** (3):235–40.
10. Bologna Working Group. *A framework for qualifications of the European higher education area*. Available from: http://www.bologna-bergen2005.no/Docs/00-Main_doc/050218_QF_EHEA.pdf; 2005 [cited 2010 3rd June].
11. European Parliament and Council. Recommendation 2008/C 111/01 on the establishment of the European Qualifications Framework for lifelong learning. *Official Journal of the European Union*; 6.5.2008.
12. Gonzales J, Wagenaar R, editors. *Universities' contribution to the Bologna process*. 2nd ed. Publicaciones de la Universidad de Duesto; 2008.
13. European Commission. *Education and training*. Available from: http://ec.europa.eu/education/index_en.htm; 2010 [cited 2010 May].
14. *Bologna process. Official Bologna process website*. Available from: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/; 2010 [cited 2010 May].
15. European Commission. *Tuning educational structures in Europe*. Available from: http://tuning.unideusto.org/tuningeu/; 2000 [cited 2010 May].
16. Mulder M. Competence development – some background thoughts. *The Journal of Agricultural Education and Extension* 2001;**7**(4):147–58.
17. White RW. Motivation reconsidered – the concept of competence. *Psychological Review* 1959;**66**(5):297–333.
18. McClelland DC. Testing for competence rather than for intelligence. *American Psychologist* 1973;**28**(1):1–14.
19. Winterton J, Delamare-Le Deist F, Stringfellow E. *Typology of knowledge, skills and competences: clarification of the concept and prototype*. Centre for European Research on Employment and Human Resources; 2005. pp. 1–108.
20. Sultana R. Competence and competence frameworks in career guidance: complex and contested concepts. *International Journal for Educational and Vocational Guidance* 2009;**9**(1):15–30.
21. Delamare-Le Deist F, Winterton J. What is competence? *Human Resource Development International* 2005;**8**(1):27–46.
22. Westera W. Competences in education: a confusion of tongues. *Journal of Curriculum Studies* 2001;**33**(1):75–88.
23. Hogg C. *Competency and competency framework*. Available from: http://www.cipd.co.uk/subjects/perfmangmt/competnces/comptfrmwk.htm; 2009 [cited 2010 25th April].
24. Woodruffe C. What is meant by a competency? *Leadership & Organization Development Journal* 1993;**14**(1):29–36.

Please cite this article in press as: Castillo J, et al., The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level, Radiography (2011), doi:10.1016/j.radi.2010.12.008

25. Rowe C. Clarifying the use of competence and competency models in recruitment, assessment and staff development. *Industrial and Commercial Training* 1995;**27**(11):12–25.
26. Semeijn JH, van der Velden R, Heijke H, van der Vleuten C, Boshuizen HPA, et al. Competence indicators in academic education and early labour market success of graduates in health sciences. *Journal of Education and Work* 2006;**19**(4):383–413.
27. Commission of the European Communities. *Commission staff working document. Towards a European Qualifications Framework for lifelong learning*. Available from: http://www.feani.org/webfeani/Statements%20EQF/EQF-EN-final%20version%20-PDF.PDF; 2005 [cited 2010 11th August].
28. Williams PL. Using theories of professional knowledge and reflective practice to influence educational change. *Medical Teacher* 1998;**20**(1):28–34.
29. Gillie Bolton. *Reflective practice, writing and professional development*. 3rd ed. Sage; 2010.
30. Hardy. Role extension and role advancement – is there a difference? A discussion paper. *Radiography* 2006;**12**(4):327–31.
31. Gonczi A. Competency based assessment in the professions in Australia. *Assessment in Education: Principles, Policy & Practice* 1994;**1**(1):27–44.
32. Mitchell BML. *Towards a competent workforce*. Gower; 1996. p. 352.
33. Smith MK. *'Competence and competencies'. The encyclopaedia of informal education*. Available from: www.infed.org/biblio/b-comp.htm; 1996 [cited 2010 24th May].
34. Milligan F. Defining and assessing competence: the distraction of outcomes and the importance of educational process. *Nurse Education Today* 1998;**18**(4):273–80.
35. Cowan DT, Norman I, Coopamah VP. Competence in nursing practice: a controversial concept – a focused review of literature. *Nurse Education Today* 2005;**25**(5):355–62.
36. McMullan M, Endacott R, Gray MA, Jasper M, Miller CML, Scholes J, et al. Portfolios and assessment of competence: a review of the literature. *Journal of Advanced Nursing* 2003;**41**(3):283–94.
37. Gonczi, A., A competency-based approach to initial and continuing professional education. Training and Professional Development in Adult and Continuing Education, 1994(1): pp. 40–47.
38. Sandberg J. Understanding human competence at work: an interpretative approach. *The Academy of Management Journal* 2000;**43**(1):9–25.
39. Burchell H. Facilitating action research for curriculum development in higher education. *Innovations in Education and Training International* 2000;**37**(3):263–9.
40. Ng CKC, White P, McKay JC. Establishing a method to support academic and professional competence throughout an undergraduate radiography programme. *Radiography* 2008;**14**(3):255–64.
41. Williams PL, Berry JE. What is competence? A new model for diagnostic radiographers: part 1. *Radiography* 1999;**5**(4):221–35.
42. Williams PL, Berry JE. What is competence? A new model for diagnostic radiographers: part 2. *Radiography* 2000;**6**(1):35–42.
43. Challen V. *Radiography tuning template, in Socrates Erasmus*; 2008.
44. Higher Education Network for Radiography in Europe. *Home page*. Available from: http://www.henre.co.uk/; 2001 [cited 2010 April].
45. Caruana CJ, Plasek J. An inventory of biomedical imaging physics elements-of-competence for diagnostic radiography education in Europe. *Radiography* 2006;**12**(3):189–202.
46. European Commission and Directorate-General for Education and Culture. *The European qualification framework for lifelong learning*. Available from: http://bookshop.europa.eu/is-bin/INTERSHOP.enfinity/WFS/EU-Bookshop-Site/en_GB/-/EUR/ViewPublication-Start?PublicationKey=NC3008272; 2008 [cited 2010 15th August].
47. Malta Qualification Council. *Referencing handbook 2010*. Available from: http://www.mqc.gov.mt/referencinghandbook2010?|=1; 2009 [cited 2010 14th August].
48. Malta Qualification Council. *Referencing of the Malta Qualifications Framework (MQF) to the European Qualifications Framework (EQF) and the Qualifications Framework of the European Higher Education Area (QF/EHEA)*. Available from: http://www.mqc.gov.mt/referencingreport?|=1; 2009 [cited 2010 15th August].
49. European Commission. Referencing to EQF: Irish and Maltese experience. *EQF Newsletter*. Available from: http://ec.europa.eu/education/lifelong-learning-policy/doc/eqf/news1_en.pdf; 2010 April.
50. The Qualifications and Curriculum Authority. *Referencing the qualifications frameworks of the United Kingdom to the European Qualifications Framework*. Available from: http://www.scqf.org.uk/News/LatestNews/NewPublicationUKQualificationsFrameworksEQFReferencingReport.aspx; 2010 [cited 2010 14th August].
51. Mike Coles. *Making the European learning area a reality. Realizing the European learning area*. Available from: http://www2.warwick.ac.uk/fac/soc/ier/glacier/qual/eqf/mike_coles_eqf.pdf; 3–5 June, 2007 [cited 2010 16th August].
52. European Commission. *Overarching framework of qualifications of the EFEA*. Available from: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/qf/overarching.asp; 2009 [cited 2010 22nd December].
53. Harris P, Vinorum A, Henner A, Lanca L, Graciano P, Vieira L, et al. *Tuning template for radiography in Europe*. Available from: http://tuning.unideusto.org/tuningeu/images/stories/template/Radiography.pdf; 2008 [cited 2010 16th August].
54. EMPIMI. Intended learning outcomes. Available from: http://www.empimi.eu//study/intended.pdf. [cited 2010 02 June].
55. Hayward Geoff et al, Degrees of success: the transition between VET and HE: Full Research Report. 2008, ESRC End of Award Report: Swindon: ESRC.
56. Calleja J. Linking VET and higher education. Is the EQF contributing to this issue ? *European Journal of Vocational Training*; 2008:156–66. 2007/3–2008/1(42/43).
57. European Parliament & Council of the European Union. *Directive 2005/36/EC of the European Parliament and of the Council of 7 September 2005 on the recognition of professional qualifications*. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:255:0022:0142:en:PDF; 2005 [cited 2010 9th August].

Please cite this article in press as: Castillo J, et al., The changing concept of competence and categorisation of learning outcomes in Europe: Implications for the design of higher education radiography curricula at the European level, Radiography (2011), doi:10.1016/j.radi.2010.12.008

ELSEVIER

Journal of Medical Imaging and Radiation Sciences 45 (2014) 37-46

Journal of Medical Imaging and Radiation Sciences
Journal de l'imagerie médicale et des sciences de la radiation

www.elsevier.com/locate/jmir

Research Article

Maltese Radiographers' Attitudes towards Continuing Professional Development: An Initial Study Using Concept Maps

Joseph Castillo, MSc[a*] and Carmel J. Caruana, PhD[b]

[a] *Medical Imaging Department, Mater Dei Hospital, Malta*
[b] *Biomedical Physics, Faculty of Health Sciences, University of Malta, Malta*

ABSTRACT

Purpose: The Council for the Professions Complementary to Medicine in Malta recently published a draft document regarding the introduction of mandatory continuing professional development (CPD) for radiographers. This study explored the attitudes and motivators of Maltese radiographers prior to the implementation of mandatory CPD in order to provide the necessary information required by management to develop CPD successfully. Concept maps are used as part of a methodology to analyse qualitative data.

Methods: All radiographers working in the National Health Service were invited to complete an anonymous web-based questionnaire.

Results: The study showed that participants generally had a positive attitude towards CPD but were concerned about the mandatory aspect. The participants were mostly motivated by increasing professional knowledge, updating existing qualifications, and enhancing the status of the profession as a whole. Radiographers identified several difficulties with respect to CPD participation, such as lack of funding, lack of management support, and not enough local CPD opportunities. CPD participation was also negatively influenced by family commitments.

Conclusion: The study showed that the majority of radiographers were self-motivated to engage in CPD activities, but there were some concerns. Based on these results, the authors suggest recommendations for allaying apprehension and producing the necessary conditions for a successful mandatory CPD scheme.

RÉSUMÉ

Objet: Le Council of Professions Complimentary to Medicine (CPCM) de la République de Malte a publié récemment une ébauche sur la mise en place de la formation professionnelle continue (FPC) obligatoire pour les technologues en radiologie. L'étude examine les réactions et les motivations des technologues en radiologie du pays avant l'implantation de la FPC obligatoire pour recueillir les données nécessaires à la direction qui souhaite instaurer une FPC obligatoire réussie. On a utilisé les cartes conceptuelles dans la méthodologie d'analyse des données qualitatives.

Méthode: Tous les technologues en radiologie des services de santé nationaux ont été invités à répondre sans s'identifier à un questionnaire affiché sur le Web.

Résultats: L'étude a démontré que les participants se montraient plutôt positifs à l'égard de la FPC, mais qu'ils s'inquiétaient qu'on la rende obligatoire. Ils étaient avant tout motivés par l'augmentation des connaissances professionnelles, la mise à niveau des compétences et la hausse générale du niveau de la profession. Parmi les difficultés citées par les technologues en radiologie au sujet de la participation à la FPC, citons le manque de fonds, le manque d'appui de la direction, le manque de formations régionales. La participation à la FPC est aussi rendue difficile par les obligations familiales.

Conclusion: L'étude a démontré que la majorité des technologues en radiologie étaient motivés à participer à des activités de FPC, mais que certaines inquiétudes étaient présentes. À partir des résultats obtenus, les auteurs ont formulé des recommandations pour dissiper l'appréhension et produire les conditions nécessaires à une FPC obligatoire réussie.

Introduction

Continuing professional development (CPD) provides a vehicle for professionals to maintain and develop their knowledge, skills, and competences (KSC) [1], where "competences" includes the attributes of responsibility and autonomy in work and study situations as defined in the European Qualification Framework [2]. This implies that practitioners should assume responsibility in an autonomous manner for their professional practice and also for their own learning [3, 4]. A CPD program should be developed by individuals or groups of professionals through a learning needs self-assessment and implemented along the continuum of lifelong learning [5]. CPD signifies a process of continuous

The author declares no conflict of interest.

* Corresponding author: Joseph Castillo, Medical Imaging Department, Mater Dei Hospital, San Gwann, Malta.

E-mail address: joseph.castillo@gov.mt (J. Castillo).

1939-8654/$ - see front matter
http://dx.doi.org/10.1016/j.jmir.2013.09.003

improvement, initiated at the entry level to the profession and leading to an expert level in order to better serve society [6] and to improve their employability [7]. Health care professionals' autonomy and engagement in setting their own learning agenda is what differentiates CPD from continuous education [8], where learning outcomes and educational activities are planned by others. Although the autonomous participation in CPD has a voluntary aspect that may be interpreted by some health professionals as a personal decision to participate in or not, health professional councils lay down standards of practice in which members are to "embrace continuing education for optimal patient care, public education and enhanced knowledge and technical competence" [9]. The delivery of health care is concerned with quality and accountability. As health care organizations strive to develop their service portfolios, employees with direct customer contact must be endowed with the necessary competences to interact with their clients and technology. Often a new service fails because personnel have not been properly trained to sell and deliver the service [10].

In 2005, the United Kingdom became the first European country to introduce mandatory CPD participation as a prerequisite for radiographers to maintain registration. A preceding voluntary program that had been running for a number of years provided the Health Professions Council and the Society of Radiographers–United Kingdom with enough data to identify those resources that were necessary for a successful mandatory CPD process. Subsequently, the Health Professions Council set up a unique CPD framework based on standards to be achieved through a mixture of learning activities relevant to current and future practice, personal contribution to practice and service development, and assessed through a written portfolio of evidence. In addition, acknowledging that there are several approaches to CPD, the Health Professions Council determined that the portfolio of evidence should not be based on a specific number of credits or hours but the creation of a portfolio of reflective writing [11, 12].

On a Europe-wide level, the published literature on CPD within radiography is scarce and a comprehensive survey of the literature only identified one publication of note [13]. This study showed that the majority of European radiographers were in favor of CPD and introduced the possibility of a common Europe-wide CPD passport for radiography practitioners. Such a passport could be linked to a detailed European competence profile referenced directly to the European Qualification Framework. However, this study focussed only on the requirements necessary for the implementation of CPD in Europe, and the authors did not investigate the attitudes and motivators of European radiographers vis-à-vis mandatory CPD as a health policy for the maintenance of national registration. A study comparing UK radiographers with those in New Zealand indicated an ambivalent attitude to the implementation of mandatory CPD among UK radiographers [14].

In late 2010, the Council for the Professions Complementary to Medicine (CPCM) in Malta published a draft document proposing mandatory CPD for radiographers and other health care professionals. In this draft, the CPCM recommended that radiographers be required to acquire a minimum of 45 CPD credits over a period of 3 years. These credits were to be selected from an approved list of activities from different categories, which included publication, self-directed learning, attendance at organized educational programs, and other professional activities (Society of Medical Radiographers–Malta, personal communication; email to J. Castillo, December 2010).

The great majority of radiographers in Malta work in the National Health Service (NHS), which includes two general hospitals, one oncology hospital, and four small health centres equipped with x-ray units. These radiologic services carry out 210,000 investigations per year and are coordinated through the medical imaging department located in the greater of the two general hospitals. Although this department does not have its own official CPD unit to monitor the KSC and learning needs of radiographers, evidence from the Society of Medical Radiographers–Malta and the Malta Magnetic Resonance Radiographers Group websites suggests that Maltese radiographers do participate in the CPD activities organized by these organizations. With the introduction of mandatory CPD, Maltese radiographers will be faced with the responsibility of identifying their learning needs and of planning their own professional development in a more structured way.

The aim of this study was to assess the situation regarding CPD attendance, attitudes and motivators among Maltese radiographers with respect to mandatory CPD prior to its implementation. The study would provide the Medical Imaging Department management with information to create communities of practice that would act as incubators for the development of staff expertise to a level consonant with the service quality targets of the organization [15, 16].

Methodology

The project was deemed to be a staff survey, and permission to conduct the study was sought from the Clinical Chair for Medical Imaging Services in Malta. The Manager for Medical Imaging Services was informed of the research project. A covering letter accompanied the questionnaire and assured participants that all responses would be treated with confidentiality and anonymity.

Design

A survey research strategy was adopted using a web-based questionnaire to collect data. This electronic collection of data was important to guarantee anonymity and confidentially; this was particularly important so as to avoid response bias as the author holds a managerial position within the Medical Imaging Department. The survey began in December 2010 and was completed in January 2011.

A published questionnaire used in a similar study for nurses [5] was modified to be directed to radiographers. The questionnaire consisted of sections addressing demographic data, occupational data, participation in and attitudes to CPD activities, and intrinsic/extrinsic motivators influencing participants' willingness to participate in CPD. The latter consisted of a list of 14 motivational statements to which a 5-point Likert-type scale was attached (ranging from "strongly disagree" to "strongly agree"). Respondents had to indicate whether each of the factors influenced their degree of participation in CPD. Participants were also queried regarding their awareness of the process of lifelong learning (LLL) and its relationship to CPD.

Sample

All 124 radiographers employed in all grades within the Maltese NHS were sent an email explaining the purpose of the study and providing them with a link to the web-based questionnaire. Radiographers with a temporary working status were excluded as their expectations may have differed with regards to CPD.

Data Analysis

Quantitative data were analysed using the statistical features provided by Excel 2007. A Cronbach's alpha coefficient test established internal consistency ($\alpha = 0.93$) for the motivator statements. Qualitative data from open-ended questions were analysed using concept maps. Concept maps have been used as a strategy to deal with the methodological challenges of qualitative research [17]. A concept map can be used to frame a research project, reduce qualitative data, analyse themes and interconnections in a study, and present findings [18]. "A concept map is a schematic device for representing a set of concept meanings embedded in a framework of propositions" ([19], p15). Concept maps are created with the broader, more inclusive concepts at the top of the hierarchy, connecting through linking words with other concepts that can be subsumed. Concept maps are an important strategy in qualitative inquiry because they help the researcher focus on meaning. The maps allow the researcher to see participants' meaning as well as the connections that participants discuss across concepts or bodies of knowledge. Additionally, the maps support researchers in their attempts to make sure that qualitative data are embedded in a particular context.

Concept maps also can be used as a strategy to search out and analyse themes in qualitative research [20]. To identify these overarching themes, the researcher has to identify interconnections between concepts. If the researcher is searching for specific interconnections, a concept map can be created from the transcripts that demonstrate these connections. For example, in one study on how professionals learn, the researcher was looking for the connections participants made between what they learned in formal continuing education programs and their professional practice [21]. Concept maps can also be used to help create a category or coding scheme in qualitative research. After the maps are created from each interview or observation, the researcher can go through them looking for levels of hierarchy, interconnections, and repeated concepts. These items then may indicate emerging themes [18].

The major disadvantage of using concept maps in qualitative work seems to be their complexity. The maps can be difficult to read for participants unfamiliar with the format, and the linkages may be harder to see as the maps get more and more complex. Additionally, the complexity at times makes it difficult for the reader to determine which concepts are of critical importance and which are of secondary importance. Because of this complexity, it is most often necessary to use other data analysis strategies in conjunction with the maps.

Concept maps in this study were used to reduce the qualitative data so as to facilitate the process of understanding key ideas (see Figure 1). They were also used as an efficient way of presenting findings. The concept maps provided an insight into the radiographers' perceptions of CPD and lifelong learning and whether they have developed the necessary values and attitudes required to promote this development.

Results

A total of 71 complete responses were returned, giving a response rate of 57%.

Demographic Profile

The data reveal a young radiography community, where 53% are between 20 and 29 years old and 29% between 30 and 39 years. As regards gender, the sample in the study was fairly balanced between males (45%) and females (55%).

The majority of the group are single (including divorced, separated, widowed) (63%), whereas 37% are married (including living with a partner). Participants having children comprised 30%. In addition, 69% of the respondents had followed an undergraduate degree program in radiography leading to professional registration. A modest group of radiographers (21%) had also followed postgraduate courses.

Occupational Profile

Radiographers in Malta work on a triple shift system (morning 07:30 AM–2:30 PM, afternoon 2:30 PM–7:30 PM, night 7:30 PM–07:30 AM of the following day). Half of the participants (50%) work morning shift only, while the rest rotate between shifts. Cross-tabulating by gender and type of shift indicated that 62% of the men work on the rotating shift system and 71% of the women work on a morning shift-only basis.

Furthermore, 66% and 32% of the respondents work in hospitals and local health centres, respectively. A small number of radiographers (18%) also do part-time work in private health settings.

CPD Participation

It was found that 63% of the respondents had participated in some form of CPD during the previous year (2010). Cross tabulating participation in CPD and working on a rotating shift basis or working morning shifts only indicates that those

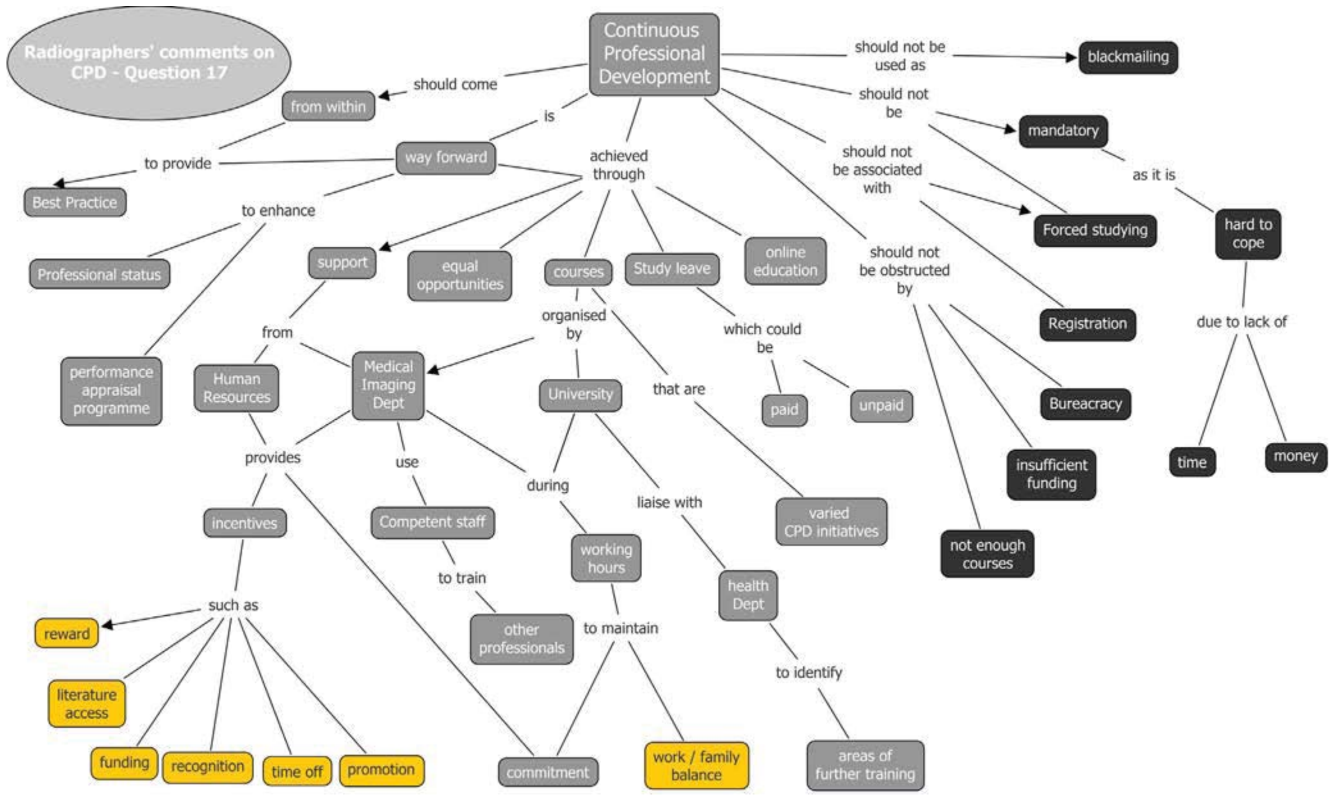


Figure 1. Concept map: Radiographers' perception of continuing professional development.

who work on a rotating shift engaged less (29%) in CPD activity than those who work mornings only (68%).

Cross tabulating CPD participation against marital status (Table 1) and having children (Table 2) indicated that CPD participation was not unduly negatively influenced by marital status but was negatively influenced by family commitments.

Respondents who attended CPD activities were also asked to state the type of event. The majority participated in local CPD activities organized by the Society of Radiographers of Malta, the Malta Magnetic Resonance Radiographers Group, the Faculty of Health Sciences of the University of Malta, the national Centre for Development Research and Training [22], and the Malta Institute of Medical Education (Table 3). Only nine had attended conferences abroad.

Radiographers were queried with regard to the amount of free time they were willing to spend on CPD and whether they have enough CPD opportunities. The group was closely split between those who are willing to spend 1 to 5 hours a month (49%) and those who were ready to spend between 6 and 10 hours a month (40%). Further, 11% were undecided. The majority of radiographers (79%) did not feel that there were enough CPD activities.

Motivational Factors

The responses on the Likert-type scale attached to the motivational statements (Table 4) were scored in order to obtain mean values in the following manner: 1 = strongly disagree, 2 = disagree, 3 = uncertain, 4 = agree, 5 = strongly agree. Increasing professional knowledge, to update my existing qualifications, and to increase the status of the profession as a whole were rated as providing most motivation. To achieve a higher educational qualification because of a previous unsatisfactory education and completing a CPD course without study leave were rated as the least motivational factors.

The Meaning of Lifelong Learning and CPD

Participants were asked for their interpretation of both CPD and LLL to determine whether the motivational factors

Table 1
Participation in Continuing Professional Development Activities against Marital Status

Participation in CPD	Single (Including Divorced, Separated, or Widowed)	Married/Living with Partner	Totals
Yes	26	19	45 (63%)
No	14	12	26 (37%)

Table 2
Participation in CPD Activities against Presence of Children

Participation in CPD	Children	No Children	Totals
Yes	11	33	44 (62%)
No	10	17	27 (38%)

CPD, continuing professional development.

Table 3
Frequency of Attendance at CPD Events

CPD Activity	Event Organizer	Responses
Conference abroad	Various	9
MRI in practice course [23]	MMRRG	18
IV therapy	FHS	8
Forensic lecture	FHS	4
Local academic onference	SMR-M	7
MSc/postgraduate courses	FHS	5
Management	CDRT	3
Basic life support	FHS	2
Ultrasound (eFAST)	FHS	8
Others	Various	8

CDRT, Centre for Development Research and Training; CPD, continuing professional development; eFAST, extended focused assessment with sonography for trauma; FHS, Faculty of Health Sciences; IV, intravenous; MMRG, Malta Magnetic Resonance Radiographers Group; SMR-M, Society of Medical Radiographers–Malta.

were relevant to the concepts of LLL and CPD. Concepts maps were used to collate all the responses into one map. Colour was used to highlight the major concepts. With regard to LLL, the radiographers' responses could be categorized according to three overarching themes: continuous learning on a personal level to improve self-development, updating of skills and knowledge to improve professional status, and daily experiential learning through formal and informal learning (Figure 2).

Radiographers' responses to the question "what do you understand by the term CPD" were categorized on five emerging themes. It was described as a management tool effectively used to share information and implement changes. It was referred to as specific subject learning related to one's profession that is either organized formally at university or informally by the medical imaging department. It was also seen as a requirement by profession and society to ensure that members update their knowledge and introduce innovations. CPD was also viewed as an academic infrastructure, part of lifelong learning related to improving professional knowledge, skills, and competences (Figure 3).

Discussion

Response Rate

It is accepted that questionnaires in the behavioural sciences generally have a response rate of approximately 56% [24]. In a population where each participant has a work-related email account, as in the case of Maltese radiographers employed in the NHS, a web survey application can achieve a comparable response rate to that of a surface mail questionnaire [25]. This study obtained a 57% response rate, which is considered an adequate response.

Constraints to CPD Participation

In a similar study investigating radiographers' attitude to CPD before the implementation of mandatory CPD in the United Kingdom and New Zealand, a general ambivalent attitude towards CPD was reported. The causes included barriers such as lack of career structures, inadequate funding or salary, lack of time for CPD during office hours, remoteness, staff shortages, and busy workloads [14]. These barriers were common to other studies involving other health care professionals [26, 27].

This study reports similar findings and foresees that releasing a number of radiographers for CPD activities could be a logistical challenge for managers especially if the opportunities for CPD activities available throughout the year are not increased. The constraints such as lack of time and support experienced by radiographers who have participated in CPD have been highlighted through a number of comments.

> I agree with CPD, however if it is compulsory then management should provide with an infrastructure which assists radiographers in achieving CPD—that is time during working hours in order to undertake CPD activities. Imaging teams have to adapt to this reality whilst management and HR have to support this good cause. More opportunities for everyone in varied CPD activities is also important. CPD can also be part of a performance appraisal programme for radiographers.

Table 4
Mean and Mode Values for Motivational Factors

Answer Options	Rating Average	Mode	Response Count
To fulfill statutory requirements to maintain registration.	3.35	4	68
I will take up a CPD course if partially funded by my employer.	3.90	4	67
I am prepared to pay for my CPD courses.	2.88	3	67
I am willing to complete a course for my CPD without study leave.	2.51	2	68
I am willing to complete a course for my CPD with partial study leave.	3.44	4	66
To obtain a further qualification in order to apply for promotion.	3.78	4	67
To update my existing qualifications.	4.31	5	68
To achieve a higher educational qualification due to previous unsatisfactory education.	2.74	2	68
I want to demonstrate that I am professionally competent.	3.98	4	66
To increase my professional knowledge.	4.61	5	69
To increase my self-esteem.	3.54	4	67
To prevent myself from becoming bored.	2.96	4	67
To increase the status of the practitioner.	3.87	4	68
To increase the status of the profession as a whole.	4.18	5	68

CPD, continuing professional development.

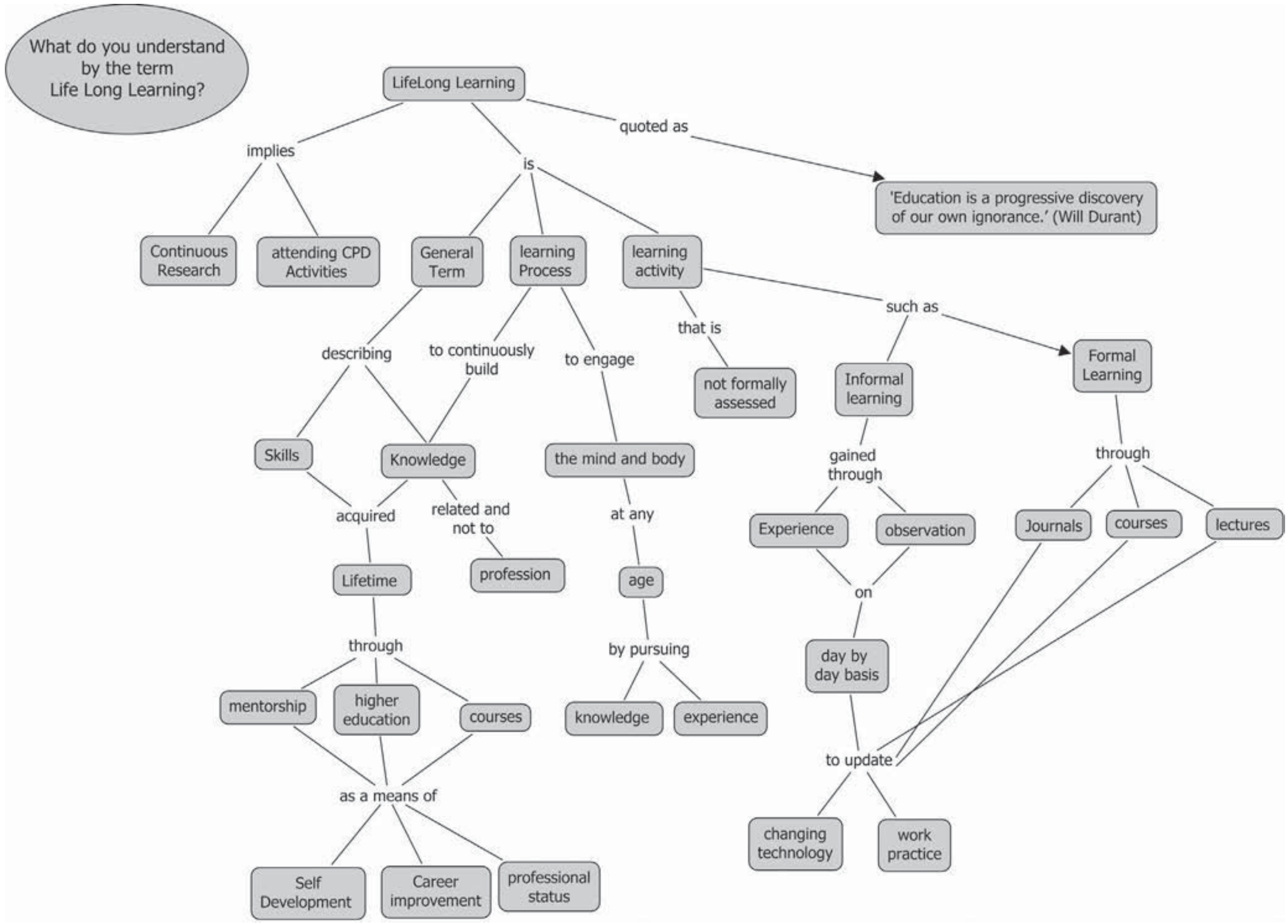


Figure 2. Concept map of radiographers' understanding of lifelong learning.

> Our department should organise CPD courses as in other health professions and motivate the Radiographers to attend these courses through incentives. The department should allow time for its personnel to attend. Another good incentive could be better access to literature.

> There definitely should be support for each professional, equally—both financially and with arrangements from management in order to allow/help workers carry out their further education. I believe that it is in management's own interest to provide means for their employees to carry out CPD.

Although CPD, whether mandatory or voluntary, is seen as a fundamental professional responsibility of the individual as laid down by the code of practice, these comments indicate that radiographers would like to see management share the responsibility and commitment for CPD. As funding remains one of the major obstacles blocking access to and motivation towards CPD, employers should cultivate a learning environment for CPD— and in so doing, accept partial responsibility for the financial outlay [28]. However, it is not just management that needs to have its role in CPD defined. The registration body, the professional society, and the Faculty of Health Science of the University of Malta all have roles to play in CPD. This shared responsibility could be achieved by setting up a dedicated CPD unit with the remit of ensuring that the learning needs of Maltese radiographers and their professional development plans as agreed by employers and as provided by educators are congruent with the requirements of the CPCM and the professional bodies [29]. Since the majority of radiographers in Malta are located within one hospital, a community of practice or a learning organization approach would be the way forward for meeting the expectations of both patients and radiographers. The community of practice would require a manager with leadership skills who works with individuals to foster a collegial culture that values change and looks at failures as an opportunity to learn and improve [30].

Radiographers who were employed on a shift basis working morning, afternoon, and night duties participated less than those who worked morning duties only. Lack of time was highlighted in the comments above as the major reason to participate less in CPD; however, this could also have happened because CPD activities are not planned to cater for those who work on shift. Repeating CPD lectures over different time periods would make it possible for all radiographers within the NHS to attend. Another possible avenue is online learning. In contrast to the study by Palarm et al

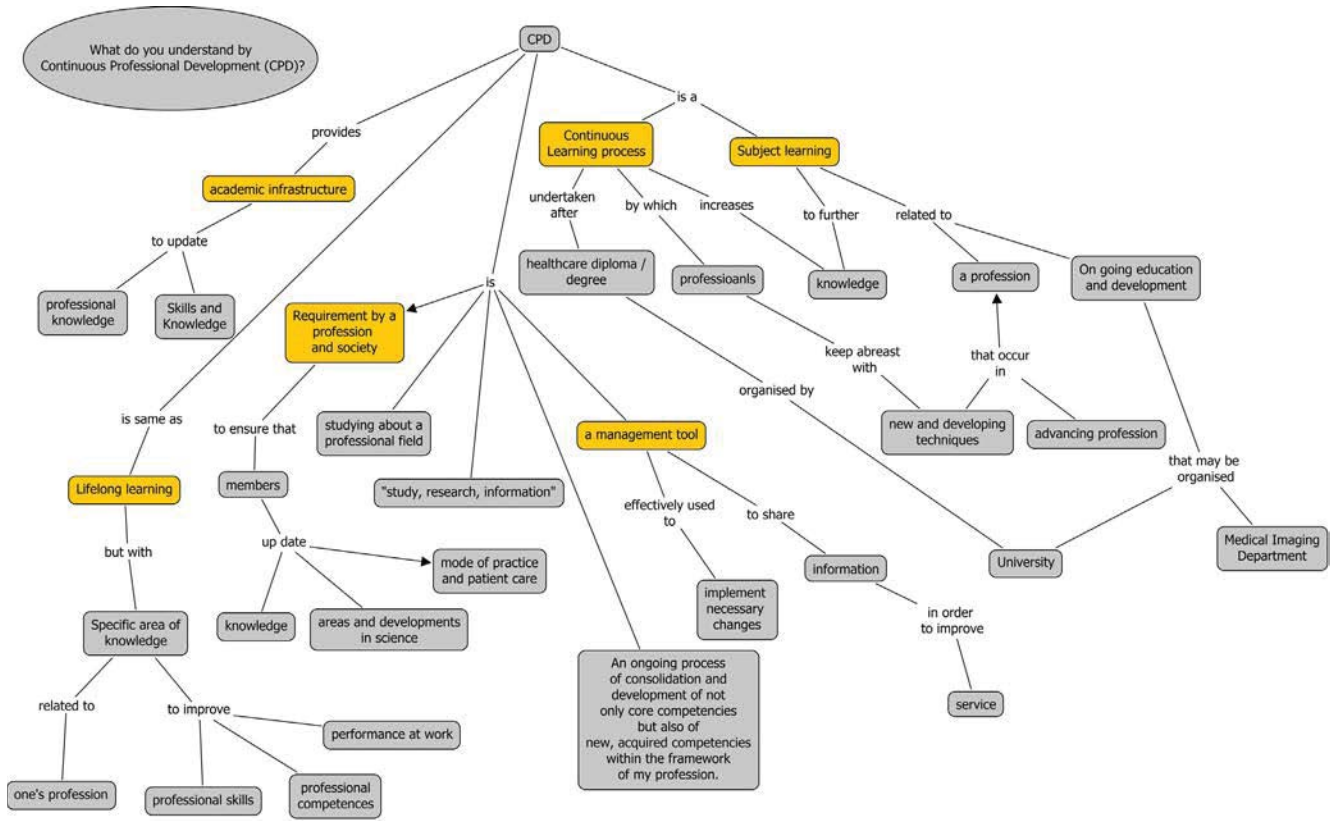


Figure 3. Concept map: Radiographers' understanding of continuing professional development.

[31], all workers working on rotating shifts in this study participated in CPD activities, indicating that flexible working hours may lead to a significant increase in CPD participation.

The majority of the radiographers (75%) were of the opinion that the spectrum of available CPD activities specific to radiography was quite narrow. However, radiographers may also be imposing restrictions on themselves as informal learning was not mentioned by any of the participants as an opportunity of learning activity for CPD. This misconception, that CPD is simply attending an event or a formal course [32], needs to be addressed as there are numerous activities that can be done by an individual without incurring any expenses except for some protected time by management. Participation in multidisciplinary meetings, journal clubs, or serving on professional committees are examples of informal learning activities [33]. This is probably because the majority of radiographers do not have reflective thinking and writing skills, the courses for which were only introduced recently in undergraduate radiography programs [34]. Therefore, it may be easier to develop a portfolio with a list of certificates obtained from formal education than evidence from informal activities that might require some short reflective essay. On the other hand, informal learning is considered by radiographers as a requirement to fulfill lifelong learning activity but one that is not necessarily specific to medical imaging practice.

Simsen et al [35] found a significant relationship among nurses from Hong Kong between marital status and educational level, with married nurses more likely to continue their study and choose generalist courses than single nurses. On the other hand, recent studies [36, 37] found no relationship between marital status and educational qualification in their studies among Australian allied health care professionals and Welsh registered nurses. In this study, no relationship was found between marital status and CPD participation. Is this the result of cultural differences, type of profession, or a direct influence of modern practices? Further study is needed to explain the different findings.

Although marital status did not affect CPD participation, family commitments and shift work negatively influenced CPD participation. This was also noted in other studies among various health professionals [38–40]. Health care organization administrators should take note of this barrier and strive to create a climate in which all health professionals irrespective of their status are able to participate in CPD activities [41, 42].

Motivation for CPD Participation

Although the motivators for participation in any CPD activity are complex and diverse, there is an agreement among the key stakeholders. Policy makers' motivators are similar to those of professional bodies and to some extent employers. Professionals and policy makers emphasize that health care professionals have a duty towards the public to keep their KSC up to date, while management literature suggests that the provision of CPD opportunities encourages the retention of health care professionals [43–45]. The setup of a learning organization, where a group of people are continuously developing their KSC, would lead to competence shifts [15, 16] that could either be sustainable as a result of technical innovation or disruptive as a result of some external market pressure that might require a move from one competence to an entirely different new competence. Examples of this competence shift within radiography are imaging interpretation and intravenous therapy resulting from the shortage of radiologists.

Research investigating motivators to CPD participation report that intrinsic motivators such as level of personal motivation, the need to improve professional knowledge and skills, and the desire to increase professional competence were the foremost motivators among the different health care professions [5, 34, 46, 47]. The real benefit of intrinsic motivators over a period of time is sustained participation and transfer to practice. However, intrinsic motivators could prevail over extrinsic motivators such as mandatory CPD or the possibility of promotion, which may not lead to sustained enthusiasm for CPD or application to practice. It is argued that whenever an external reward is offered for behaviour, the motivation is not bound as tightly to the behaviour. Consequently, forcing adults to undertake learning will not guarantee that learning has indeed contributed to professional and service development [30].

What is interesting in this study is that the results demonstrated that radiographers were generally internally motivated towards CPD. The concept map in Figure 1 indicates that there are a lot more positive concepts towards CPD (grey) than there are negative ones (black). The concept map also features a number of incentives (yellow) that were mentioned by radiographers as likely to improve CPD participation. This augurs well for the Maltese radiography profession and would aid in its endeavours to avoid professional obsolescence where current competence may no longer be sufficient for effective performance [30]. Another motivating factor that featured prominently in the results was "increasing professional competence" highlighting the strong association between the desire for competence enhancement and CPD. However, in this study, the external motivator of obtaining further qualification to apply for promotion was also high. This idea that acquiring a qualification will result in promotion is a misconception that is attributed in part to a strong competition for the few senior posts among a large community of young radiographers all working with the same employer and the lack of other job opportunities in radiography outside the local NHS. This attitude is also fueled by the fact that sectoral trade union agreements promote those who obtain university degrees such as master's degrees to a higher salary scale. This needs to be revisited (renegotiated) because promotion decisions should be dependent on the individual's job-specific and general skills based on continuous skill development and training and not the number of qualifications [48]. This concept merits further investigation.

On the other hand, completing a CPD course without study leave and doing CPD to avoid boredom or to increase self-esteem were the least motivational factors. Doing CPD as a statutory requirement to maintain registration was also not seen as a motivational factor. This was further highlighted with the following comments:

> Employer should support CPD during working hours as this enhances the development of the employee and not penalizes her through loss of leave or time in lieu.

> I think the employer should at least provide study leave even if unpaid for the CPD courses of the employees.

> CPD should not be associated with our registration. Certain radiographers already find it hard to cope as it is so it should not be obligatory. I agree that there should be an incentive, such as promotion; but it shouldn't have anything to do with one's registration. Blackmailing people is not an incentive for CPD!

> CPD should not be accompanied by enforced extensive studying. Work/family balance should be maintained. Time off from work should be incorporated in CPD planning otherwise time dedicated to family/leisure will be eroded.

> I agree with CPD however if it is compulsory then management have to provide an infrastucture which assists radiographers in achieving CPD—that means time during working hours in order to undertake CPD activities. Teams have to adapt for this reality while management and HR have to support this good cause. If not resistance to change will push CPD out. More opportunities for everyone in varied CPD activities is also important. CPD can also be part of a performance appraisal programme for radiographers.

> Employers should provide funding and study leave to encourage staff to attend CPD activities. However, care should be taken in areas were there are severe shortages of staff.

The above difficulties were the main reasons why participants prefer that CPD participation should not be made mandatory. Therefore, in order to increase participation in the CPD program, some form of support should be available from the employer and professional groups. It was also mentioned that for CPD to be worthwhile there should be a variety of activities that address local needs rather than copying verbatim what is happening abroad. As one participant stated,

> I think that overall mandatory CPD is a very good thing if introduced properly. What works in one country doesn't mean that it is going to work in Malta. There should be a wide variety of CPD activities that the individuals can do to maintain registration. This is important as not everyone has the time and money to attend CPD courses. I think that the employers should support all the employees to fulfill

> CPD requirements. Although the government is providing money for CPD activities, I think that there is too much bureaucracy in obtaining this money. It took me 3 years to get the CPD money. Also the money is definitely not sufficient in areas where there is no training available in Malta.

The Meaning of LLL and CPD

In Ryan's study [5], participants acknowledged that LLL was a combination of general experiences that helped participants to identify their strengths and weakness through reflection. In this study, the open-ended responses clearly showed that radiographers make a clear distinction between LLL as a generic process of ongoing learning and CPD as a specific process for professional development related to radiography. Although radiographers mentioned experiential learning as an opportunity towards LLL, it is apparent that learning through reflection is not included in the radiographers' range of learning methodologies. This is probably the result of not practicing reflective thinking during their undergraduate education or because portfolios for which reflective commentary is a necessary requirement are not yet being used. This may change with the introduction of mandatory CPD, which is expected to be assessed by a portfolio of evidence.

Conclusion and Recommendations

This study has provided new knowledge for the radiography profession in Malta. The majority of radiographers were self-motivated to engage in CPD activities since CPD provides a method for increasing their knowledge, improves their existing skills, and enhances professional competence. The majority of the participants do not see participation in CPD as a statutory requirement or an important motivational factor. Formal and structured CPD activities are given much credit and valued more than informal learning. Reflective learning and writing is not practiced. The main constraints experienced by the radiographers were lack of CPD opportunities, funding, and support from management.

It is the opinion of the researchers that radiographers, employers, and the professional groups (Society of Medical Radiographers–Malta and Malta Magnetic Resonance Radiographers Group) should work together to increase opportunities for CPD as no stakeholder can take sole responsibility for the delivery of a successful CPD program. The authors recommend that if CPD is to become mandatory, regulations should be laid down making employers share joint responsibility for the setting up of CPD structures within the workplace. Medical imaging departments (through their human resources sections) must strive to enhance learning in the workplace through learning approaches such as experiential learning [49], communities of practice [50, 51], learning organizations [52], and online learning, among others. Encouragement through incentives, such as study leave and protected time to organize lectures during office hours, may increase participation in a mandatory CPD program. The authors query whether the mandatory CPD scheme based on a number of formal learning activities is the best way for such a relatively small group of radiographers who are mostly employed in a single hospital. Instead, the authors suggest a mandatory CPD scheme based on a portfolio of evidence that addresses a set of standards that are relevant to the individual health professional and the medical imaging services in Malta. This would lead to greater flexibility in the content and timing of CPD activities.

References

[1] Gosling, S. (1999). CPD and competence: related but different: an initial consideration of concepts. *Physiotherapy* 85, 536–540.

[2] European Commission (2008). *The European Qualification Framework for Lifelong Learning (EQF).* Luxembourg: Office for Official Publications of the European Communities.

[3] Hardy, M., & Snaith, B. (2006). Role extension and role advancement—is there a difference? A discussion paper. *Radiography* 12, 327–331.

[4] Williams, P. L. (1998). Using theories of professional knowledge and reflective practice to influence educational change. *Med Teacher* 20, 28–34.

[5] lsop, A. (2013). *Continuing Professional Development in Health and Social Care: Strategies for Lifelong Learning.* John Wiley & Sons.

[6] Eraut, M. (1994). *Developing professional knowledge and competence.* New York: Routledge.

[7] Sadler-Smith, E., Allinson, C., & Hayes, J. (2000). Learning preferences and cognitive style. *Manage Learning* 31, 239.

[8] Boyes, C. (2004). Discourse analysis and personal/professional development. *Radiography* 10, 109–117.

[9] Council for the Professions Complimentary to Medicine. (2006). Code of practice—radiography. Available at: https://ehealth.gov.mt/HealthPortal/others/regulatory_councils/professions_compl._to_medicine/professions_compl_to_medicine.aspx. Accessed September 13, 2013.

[10] Edvardsson, B., Meiren, T., Schäfer, A., & Witell, L. (2013). Having a strategy for new service development—does it really matter? *J Service Manage* 24, 25–44.

[11] Health Professions Council (2009). *Continuing Professional Development and Your Registration.* London: Health Professions Council.

[12] Chetcuti, D. (2007). The use of portfolios as a reflective learning tool in initial teacher education: a Maltese case study. *Reflective Pract Int Multidisciplinary Perspect* 8, 137–149.

[13] Marshall, G., Punys, V., & Sykes, A. (2008). The continuous professional development (CPD) requirements of radiographers in Europe: an initial survey. *Radiography* 14, 332–342.

[14] Henwood, S. M., Yielder, J., & Flinton, D. (2004). Radiographers attitudes to mandatory CPD: a comparative study in the United Kingdom and New Zealand. *Radiography* 10, 251–258.

[15] Drejer, A., & Riis, J. O. (1999). Competence development and technology: how learning and technology can be meaningfully integrated. *Technovation* 19, 631–644.

[16] Drejer, A. (2001). How can we define and understand competencies and their development? *Technovation* 21, 135–146.

[17] Novak, J. D., & Cañas, A. J. (2008). *The theory underlying concept maps and how to construct and use them.* Florida Institute for Human and Machine Cognition Pensacola Fl. Available at: wwwl.ihmc.us. [http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm]. Accessed September 25, 2013.

[18] Daley, B. J. (2004). Using concept maps in qualitative research. Paper presented at: First International Conference on Concept Mapping. September 14, 2004; Pamplona, Spain. Citeseer.

[19] Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* Cambridge: Cambridge University Press.

[20] Burgess-Allen, J., & Owen-Smith, V. (2010). Using mind mapping techniques for rapid qualitative data analysis in public participation processes. *Health Expect* 13, 406–415.

[21] Daley, B. J. (2001). Learning and professional practice: a study of four professions. *Adult Educ Q* 52, 39–54.

[22] CDRT. Centre for Development Research and Training. (2011). Available at: http://cdrt.gov.mt/home?l=1. Accessed January 16, 2011.

[23] Talbot, J., & Wesrbrook, C. (2011). MRI education. Available at: http://www.mrieducation.com/courses/index.html. Accessed March 10, 2011.

[24] Baruch, Y. (1999). Response rate in academic studies—a comparative analysis. *Hum Relat* 52, 421.

[25] Kaplowitz, M. D. (2004). A comparison of web and mail survey response rates. *Public Opin Q* 68, 94.

[26] Murphy, C., Cross C., & McGuire, D. The motivation of nurses to participate in continuing professional education in Ireland. *J Eur Indust Training* 30, 365–384.

[27] Yfantis, A., Tiniakou, I., & Yfanti, E. (2010). Nurses' attitudes regarding Continuing Professional Development in a district hospital of Greece. *Health Sci J* 4, 193–200.

[28] Barr, H. (2000). New NHS, new collaboration, new agenda for education. *J Interprofess Care* 14, 81–86.

[29] Henwood, S., Edie, J., Flinton, D., & Simson, R. (1998). Continuing professional development—a re-examination of the facts. *Radiography* 4, 5–8.

[30] Knight, P. (1998). Professional obsolescence and continuing professional development in higher education. *Innov Educ Training Int* 35, 248–256.

[31] Palarm, T., Jones, K., & Gilchrist, M. (2001). Personal and professional development: a survey of radiographers employed in the South West Region. *Radiography* 7, 43–53.

[32] Boud, D., & Hager, P. (2012). Re-thinking continuing professional development through changing metaphors and location in professional practices. *Stud Continuing Educ* 34, 17–30.

[33] Salzman, A., & Hall, K. D. (2013). Human resource development and continuing professional development of physical therapists. *Human resource development in the public sector: the case of health and social care*, p. 296.

[34] Lee, S., Reed, W., & Poulos, A. (2010). Continuing professional development: the perceptions of radiographers in New South Wales. *Radiographer* 57, 33–39.

[35] Simsen, B. J., Holroyd, E., & Selhck, K. (1996). Postgraduate education expectations: a survey of Hong Kong graduate nurses. *J Adv Nurs* 24, 827–835.

[36] Stagnitti, K., Schoo, A., Reid, C., & Dunbar, J. (2005). Access and attitude of rural allied health professionals to CPD and training. *Int J Ther Rehabil* 12, 355–362.

[37] Ryan, J. (2003). Continuous professional development along the continuum of lifelong learning. *Nurse Educ Today* 23, 498–508.

[38] Clifford, R. M., Ram, P. L., & Lakos, A., et al. (2011). Post-registration learning trends of community pharmacists. *J Pharm Pract Res* 41, 203.

[39] Moons, K., Evans, S., Lightowlers, M., Bullock, A., & Barnes, E. (2012). Dental nurses' perception of CPD in Wales. *Vital Stat* 9, 19–23.

[40] Sykes, H., & Temple, J. (2012). A systematic review to appraise the evidence relating to the impact and effects of formal continuing professional education on professional practice. *J Nurs Educ Pract* 2, 194.

[41] Haywood, H., Pain, H., Ryan, S., & Adams, J. (2012). Engagement with continuing professional development: development of a service model. *J Allied Health* 41, 83–89.

[42] Brekelmans, G., Poell, R. F., & van Wijk, K. (2013). Factors influencing continuing professional development: a Delphi study among nursing experts. *Eur J Training Dev* 37, 313–325.

[43] Eberhard, J., Reinhardt-Mondragon, P., & Stottlemyer, B. (2000). *Strategies for new teacher retention: creating a climate of authentic professional development for teachers with three or less years of experience. ERIC No. ED450116*. Corpus Christi, TX: Texas A&M University.

[44] Probst, H., & Griffiths, S. (2007). Retaining therapy radiographers: what's so special about us? *J Radiother Pract* 6, 21–32.

[45] Perkins, A., & Kron, T. (2007). Continuing professional development needs of Australian Radiation Oncology Medical Physicists—an analysis of applications for CPD funding. *Australas Phys Eng Sci Med* 30, 226–232.

[46] Gould, D., Drey, N., & Berridge, E. (2007). Nurses' experiences of continuing professional development. *Nurse Educ Today* 27, 602–609.

[47] French, H. P., & Dowds, J. (2008). An overview of continuing professional development in physiotherapy. *Physiotherapy* 94, 190–197.

[48] Prasad, S., & Tran, H. (2013). Work practices, incentives for skills, and training. *Labour Econ* 23, 66–76.

[49] Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall.

[50] Wenger, E., McDermott, R., & Snyder, W. (2002). *A guide to managing knowledge. Cultivating communities of practice*. Boston, MA: Harvard Business School Press.

[51] Andrew, N., Tolson, D., & Ferguson, D. (2008). Building on Wenger: communities of practice in nursing. *Nurse Educ Today* 28, 246–252.

[52] Greenwood, J. (1993). Reflective practice: a critique of the work of Argyris and Schön. *J Adv Nurs* 18, 1183–1187.

Radiography xxx (2014) 1–7

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020

J. Castillo [a,*], C.J. Caruana [b], P.S. Morgan [c], C. Westbrook [d]

[a] Mater Dei Hospital and Faculty of Health Sciences, University of Malta, Malta
[b] Biomedical Physics, Faculty of Health Sciences, University of Malta, Malta
[c] Medical Physics and Clinical Engineering, Nottingham University Hospitals, Nottingham, NG7 2UH, UK
[d] Faculty of Health, Social Care and Education, Anglia Ruskin University, Cambridge, UK

A R T I C L E I N F O

Article history:
Received 4 February 2014
Received in revised form
12 August 2014
Accepted 9 September 2014
Available online xxx

Keywords:
MRI
Service portfolio
Delphi technique
Forecasting

A B S T R A C T

Purpose: As high quality CPD courses become increasingly expensive and time off for radiographers progressively limited, it is important that CPD content be aligned to forecasted service portfolio development. When such a portfolio has not been developed locally the CPD planner should carry out an own forecasting exercise. The purpose of the study was to develop a 2020 MRI service portfolio using a Delphi study.
Methods and materials: MRI stakeholder experts participated in a first Delphi round based on semi-structured interviews. The interviews were analysed thematically leading to a series of statements for a second Delphi round. Level of agreement was assessed as the median value on a 6 point Likert scale ranging from 1 (complete disagreement) to 6 (complete agreement), the level of consensus was assessed using the interquartile range (IQR). Consensus was defined as IQR ≤ 1.
Results: Very strong agreement and consensus (median 6, IQR ≤ 1) was obtained for maintaining current service catalogue and introduction of breast biopsies, cardiac studies, ISO standards, referral guidelines, and departmental policies aligned to EU regulations. Strong agreement and consensus (median 5, IQR ≤ 1) was obtained for introduction of tumour assessment, tractography, elastography, enterography. The level of consensus was low (IQR ≥ 1) regarding research, 3T MRI, outsourcing, prostate screening and certification for MRI referral privileges.
Conclusion: The multi stakeholder approach adopted ensured that the proposed service portfolio would be suitable for local healthcare needs. Although the methodology has been applied to MRI it could easily be adapted to any imaging modality.

Introduction

Magnetic Resonance Imaging (MRI) is now a leading imaging modality; new applications are constantly being introduced whilst the number of patient examinations is ever on the increase.[1–5] Since 2008, MRI utilization rates in Malta have increased by 96% with new requests contributing towards an ever increasing waiting list.[6,7] The need for high quality continuous professional development (CPD) for local MRI radiographers is therefore expected to become acute over the next years.

This study forms part of a wider project on CPD for MRI senior radiographers in Malta. Underpinning the focus of the study is a situation most radiographer managers will recognise: high quality CPD courses are becoming increasingly expensive and time off for radiographers progressively limited owing to higher workloads. In such circumstances, it is important that CPD time is optimized by ensuring that content reflects more closely the specific learning needs of the particular group of radiographers for whom it is designed and the particular healthcare needs of the local population.[8] CPD content should be aligned to the forecasted future development of the local service portfolio the radiographers would be expected to deliver ('service portfolio' refers to the range of services envisaged to be offered by the service). When such a service portfolio has not been sufficiently developed locally it is

* Corresponding author. Tel.: +356 25456773.
E-mail addresses: joseph.castillo@gov.mt (J. Castillo), carmel.j.caruana@um.edu.mt (C.J. Caruana), paul.morgan@nottingham.ac.uk (P.S. Morgan), Catherine.westbrook@anglia.ac.uk (C. Westbrook).

http://dx.doi.org/10.1016/j.radi.2014.09.003
1078-8174/

important that the CPD planner carries out an own forecasting exercise to assess what the service would likely look like on the target date (in this case 2020).

Initial literature review and correspondence with international colleagues indicated that the way services are developed varies widely. One approach involves the development of international or country-wide guidelines set up by groups of experts. Unfortunately, such guidelines often take too long to be formulated and disseminated and frequently require extensive adaptation for use at the local level where service development and device procurement decisions ultimately need to be taken.[9–11] On the other hand, in the case of smaller institutions, decision making is sometimes based on individual physician subjective preference or be excessively vendor influenced. This may lead to decisions which do not always support closely the healthcare needs of local patients.[12–14]

The issue of the direction service portfolio development should take represents a formidable challenge to departmental managers, however, it also offers opportunities for research. This article presents one possible way forward that avoids the pitfalls of the two aforementioned approaches. This study therefore answers the question: how may a radiography manager guided by a patient oriented and inter-professional/multi-stakeholder philosophy and who is faced with a need for forecasting of service development tackle the situation? The authors propose a methodology based on a multi-stakeholder and inter-professional Delphi group. Although the methodology has been applied to MRI it could easily be adapted to any imaging modality.

Service portfolio

Fig. 1 depicts the service portfolio model that guided the study and is a simplified version of that proposed by Brailsford and Vissers.[15] A well-defined service portfolio helps stakeholders understand the services that are/may be offered and hence promotes communication and consensus among stakeholders. A well-managed service portfolio ensures that existing services are maintained and not negatively impacted when any new functionality or service is introduced[16]; it enables institutions to allocate resources to identified healthcare needs, thereby enabling a more effective and efficient service.

Method

The research technique chosen was the Delphi technique as it is suitable when idea generation and exploration, forecasting and expert judgment are indispensable.[17–19] The technique is well established in healthcare and educational research and the search word 'Delphi' in Pubmed currently gives close to five thousand hits. The researcher sought to gather opinions from a purposive sample of key stakeholder experts ($n = 17$) that make the most use of the MRI services. The panel included experts in healthcare policy, diagnostic radiology, imaging unit management, orthopaedics, neurology, medical physics, MRI industry and patient advocates. Gillham[20] refers to this approach as the 'elite interview'. A focus group or a nominal group technique could have been employed in collecting the data. However, considering the diversity of professions and grade levels within the group, the Delphi was most suitable as it ensures maximum participant autonomy and the possibility of opinion modification following successive Delphi rounds.[21–23] The main limitations of Delphi are the wide variation in what is regarded as consensus and the fact that it may be too time consuming for participants, risking participant attrition between successive rounds.[23] In this study the effects of the former limitation were minimized by using objective quantifiable criteria: median for level of agreement/disagreement and inter-quartile range (IQR) for extent of consensus.[24] The criterion for consensus was an IQR less or equal to 1 which is stringent. The latter limitation was addressed by utilizing individual interviews for the first round of the Delphi. Interviews increase participation and the use of face to face interviewing is especially appropriate with participants in leadership positions whose time may be very limited.[25] Although the respondents were known to the researcher, they were kept anonymous to each other. The anonymity of the experts would prevent the dominance of the strongest and most eloquent speakers therefore enabling the study to be informed by the views of the less confident speakers. Ethical approval was granted by the research ethics committee of the University of Malta.

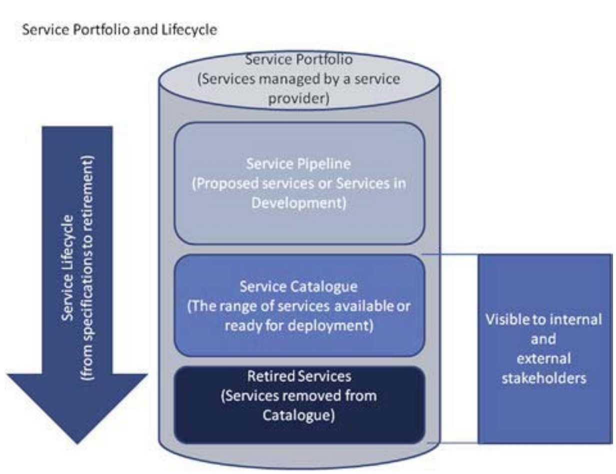


Figure 1. Model of the service portfolio guiding the research study.

Delphi first round

The first round of the Delphi was carried out through semi-structured interviews to provide maximum opportunity for idea generation and elaboration.[26] The interview tool was based on the service portfolio model shown above and was divided into 4 sections. Section 1 focused on the interviewee's role in MRI and potential influence on the MRI service portfolio; section 2 focused on the service catalogue with a list of services that are presently available or ready for implementation; sections 3 and 4 were respectively dedicated to services in the pipeline and those prone to possible sidelining.

A letter of invitation to participants provided an information sheet and consent form. The participants were provided with the interview questions in advance so that they might reflect on the issues prior to being interviewed. Questions were sequenced to lead the discussion towards the key questions of the study.[27] The subsequent qualitative analytical process used was based on Braun and Clarke's six phase framework.[28] Concept maps were created for each interviewee using CMAPTOOLS[29] and subsequently analysed by one researcher for levels of hierarchy, interconnections and repeated concepts to identify emerging themes and elaborate on those previously identified from the literature.[8,30] Each map was sent to the respective participant for correction and verification. An example of a concept map generated during the project can be found in Fig. 2.

Delphi second round

A web based second-round questionnaire was based on the themes generated in the first round. The second round of the Delphi study was conceived as a consensus seeking round in which

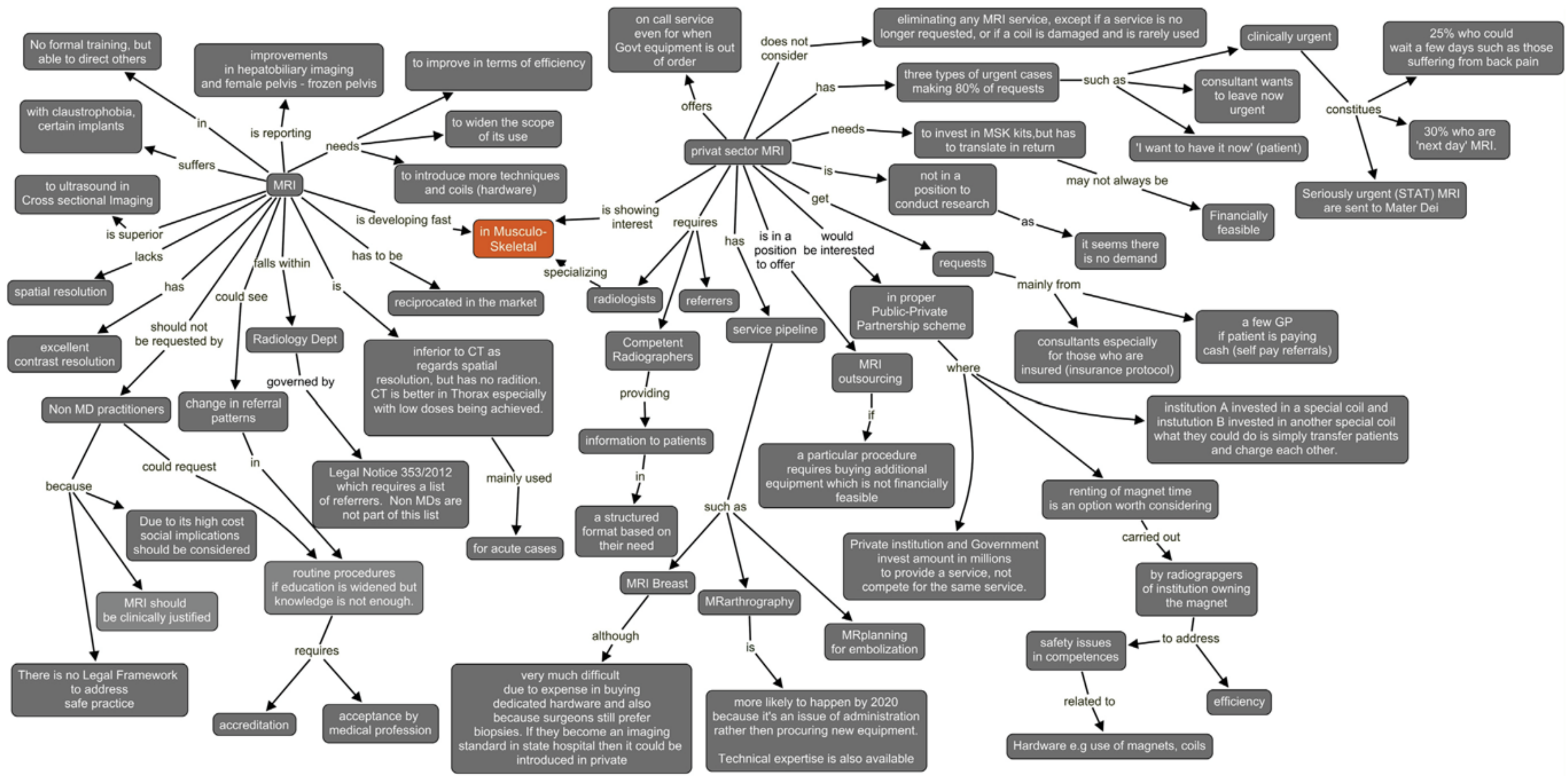


Figure 2. Concept map – manager radiography interview.

participants were asked to register their level of agreement/disagreement with a list of close-ended statements generated from first round data. The following Likert scale was used: 1 = completely disagree, 2 = generally disagree, 3 = slightly disagree, 4 = slightly agree, 5 = generally agree, 6 = completely agree. No neutral ('neither agree nor disagree') point was used as suggested by Beaudin[31] but each participant was given the option to comment on each statement.

Results

The response rate in the first round was 65% ($n = 11$). Non respondents in the first round were re-invited to participate in the second round. The response rate in the second round increased to 88% ($n = 15$). The composition of the expert panel for the second round is shown in Table 1. Since the non-respondents in the first round did not have additional comments it was considered that the second round questionnaire included all views to their satisfaction. Each expert in the panel had more than 9 years of experience in MRI.

The coding process as described by Nvivo 10 (www.qsrinternational.com) was carried immediately after the first round interviews. This resulted in 216 references which were grouped into nodes which later became the themes. The final list of themes was:

- staff and public education
- research
- current procedures
- technical expertise
- future services and technology
- legislation, quality and safety considerations
- accessibility to patients and non-medical referrers
- retired services

These themes guided the development of the statements for the second round questionnaire.

The tool with corresponding results for the second round of the Delphi is shown in Table 2. The measures of level of agreement/disagreement with the statement and consensus were the median and IQR respectively.[25,32,33] Delphi studies are often stopped when an IQR of 1.0 or less is attained on the greater majority of the probed statements.[34] In this study 90% of the statements achieved an IQR of 1.0 or less following the second round. The Delphi was therefore stopped at that stage. All statements achieved a high level of agreement: 26 statements achieved a median of 6, 15 statements a median of 5. In terms of level of consensus, 3 achieved an IQR of 0 (total consensus), 33 statements resulted in an IQR of between 0.1 and 1.0 (high to medium level of consensus) and 5 an IQR higher than 1.0 (medium to low consensus, these are shown shaded in the table). The distribution of responses for each statement was checked for unimodality before calculation of median and IQR.[25]

Table 1
List of participants in second round.

Participants	Number of participants
Surgeons (Neuro and orthopaedic)	2
Radiologists	2
Neurologist	1
Managers (Radiography, medical physics, physiotherapy)	3
Policy maker at Ministry for Health	1
Patient advocates	2
Director of company importing medical imaging equipment	4
Total	15

Discussion

The results of the Delphi are discussed individually below by theme. Numbers in brackets refer respectively to statement number, corresponding median and corresponding IQR.

Staff and public education

MRI education in Malta includes an MSc Radiography (MRI) of the University of Malta and an MSc Medical Physics which includes MRI for physicists majoring in Diagnostic and Interventional Radiology. Radiologists follow the programme of the Royal College of Radiologists (UK). Participants strongly agreed that the present MRI educational provision to all professions should be quality assured (23, 6.0, 1.0) and that it be widened to include MD and non-MD referrers (21 ,5.0, 1.0). MRI legislation education should be also made available to all healthcare professionals (25, 6.0, 0.5). This is crucial owing to the highly debated 2004/40/EC directive on minimum and health and safety requirements during work carried out in electromagnetic fields. The European Commission issued a call for tender for good practice guidance on MRI safety.[35] Public education also registered high agreement and consensus (20, 6.0, 1.0) with many of the participants suggesting ways how to achieve this: *"I think that if we use the same model as that used in the healthcare fair we would reach many people"* (Director of company).

Research

Participants confirmed that very little research is being carried save some MSc projects by radiographers. Although participants were generally in favour of research, the level of consensus was low (24, 5.0, 2.0). The high IQR resulted from the low level of enthusiasm for research by the private sector. This was expected as in the present circumstances research does not lead to profit locally. However all participants reiterated that they would support all requests from individuals or group of healthcare professionals to carry out research.

Current procedures

The results indicate that participants still consider MRI as the gold standard for patients who require neurosurgical or orthopaedic operations as well as those who require neurological investigations (2, 6.0, 1.0; 4, 6.0, 0.0; 8, 6.0, 0.5; 14,6.0, 0.5). Clinicians expect that requests for MRI services are going to increase further: *"We need MRI services and our requests are going to increase"* (Orthopaedic surgeon).

Technical expertise

The group highlighted the importance of utilizing protocols that address specific clinical questions rather one protocol fits all (17, 5.0, 1.0). Magnet time is expensive and additional sequences and unnecessarily long scanning times are undesirable.[36] "*Yes definitely for example if a haemangioma can be diagnosed with just two sequences then we should stop there. Same applies to brain. Obviously that would involve either the presence of a radiologist or that decision has to be delegated to senior radiographers*" (Radiologist). Other participants suggested augmented roles for radiographers and medical physicists in quality assurance programmes (25, 6.0, 0.5),

Please cite this article in press as: Castillo J, et al., Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020, Radiography (2014), http://dx.doi.org/10.1016/j.radi.2014.09.003

Table 2
Statements for the second round of the Delphi with corresponding median and IQR values.

Statement no	Statement	Median	IQR
MRI service catalogue			
1	Demographic information	–	–
2	Neurology MRI including diffusion weighted imaging should continue to form part of the service catalogue.	6.0	1.0
3	Body MRI should continue to form part of the service catalogue.	6.0	1.0
4	Musculoskeletal MRI should continue to form part of the service catalogue	6.0	0.0
5	Vascular MRI should continue to form part of the service catalogue	6.0	1.0
6	Breast MRI should continue to form part of the service catalogue	6.0	1.0
7	MR cholangiopancreatography (MRCP) should continue to form part of the service catalogue.	6.0	1.0
8	MR neurography (e.g Brachial plexus) should continue to form part of the service catalogue.	6.0	0.5
9	MRI prostate imaging should continue to form part of the service catalogue.	6.0	1.0
10	MRI female pelvis should continue to form part of the service catalogue.	6.0	1.0
11	Paediatric MRI should continue to form part of the service catalogue	6.0	1.0
12	MRI with general anaesthesia should continue to form part of the service catalogue	6.0	0.5
13	MR arthrography should continue to form part of the service catalogue.	6.0	1.0
14	MRI planning for Deep Brain Stimulation should continue to form part of the service catalogue.	6.0	0.5
15	On call services should continue to be provided on a 24/7 basis.	6.0	1.0
16	Outsourcing should only be considered after all other options in reducing the waiting time have failed.	5.0	2.0
MRI service pipeline by 2020			
17	Information on the diagnostic utility of different pulse sequences in the various areas of healthcare should be provided to healthcare professionals.	5.0	1.0
18	Information on MRI legislation should be provided to all healthcare professionals.	6.0	1.0
19	Evidence based referral guidelines should be made available to all MRI stakeholders.	6.0	0.5
20	Information about the strengths, limitations and safety of MRI should be made available to the general public.	6.0	1.0
21	MRI courses should be developed for MD and non-MD referrers.	5.0	1.0
22	All referrers should be certified in MRI referral before being granted MRI referring privileges.	5.0	1.5
23	MRI education to all professions involved in MRI should be quality assured.	6.0	1.0
24	All professions involved with MRI should participate in research	5.0	2.0
25	Local MRI departmental regulations and procedures should be constantly updated to any EU legislation and documentation.	6.0	0.5
26	Referral guidelines would be used to prioritize accessibility to services.	6.0	0.0
27	Standard operating procedures regulating non-MD referrals would be needed as non-MD referrals will become more common.	6.0	1.0
28	MR tractography (MRI of neural tracts of the brain) should form part of the MRI service catalogue	5.0	1.0
29	3T Imaging should form part of the MRI Service catalogue.	5.0	2.0
30	MRI guided biopsy of the breast should form part of the MRI service catalogue.	6.0	1.0
31	Diffusion weighted imaging for non cerebral work should form part of the MRI service catalogue.	5.0	1.0
32	Cardiac MRI should form part of the MRI service catalogue.	6.0	1.0
33	Breast MRI as a screening tool for family screening should form part of the MRI service catalogue.	5.0	1.0
34	Oncology planning with MRI fusion imaging should form part of the MRI service catalogue.	5.0	1.0
35	MRI-PET should form part of the MRI service portfolio.	5.0	1.0
36	Elastography imaging which is used for evaluating liver cirrhosis should form part of the MRI service catalogue	5.0	1.0
37	Dynamic MRI for patellar tracking should form part of the MRI service catalogue.	5.0	1.0
38	MRI enterography (small intestine imaging) should form part of the MRI service catalogue.	5.0	1.0
39	Prostate MRI as a screening tool should form part of the MRI service catalogue.	5.0	1.5
40	Assessment of change in tumour burden as a measure of treatment response or tumour progression should form part of the MRI service portfolio.	5.0	0.5
41	The quality and safety of the MRI service should be ISO assured.	6.0	0.0
MRI services to be sidelined			
42	Given the present level provision of MRI services none of the present services should be sidelined.	6.0	1.0

in serving as interlocutors between patients/referrers and the MRI unit (20, 6.0, 1.0) and in a patient and occupational safety[37,38]:

Future services and technology

Introduction of MR tractography, elastography, dynamic MRI for patellar tracking, DWI for non-cerebral work, MRI enterography, oncology planning and MRI-PET received a median of 5.0 and IQR of 1.0; Cardiac MRI achieved a higher level of agreement (32, 6.0, 1.0). There was less consensus on the introduction of 3T and prostate cancer screening (IQR = 2.0, 1.5 resp.). This is quite surprising because prostate cancer detection and characterization has benefited from the introduction of 3T MRI scanners, improved DWI sequences with fewer artifacts, better image-processing methods and MRI guided biopsy.[39–43] In addition Ahmed et al.[44] reiterate that the use of MRI before biopsy can serve as a screening tool in men with raised serum prostate-specific antigen and lowers costs by reducing biopsies. This result is likely to have been influenced by the fact that the sample size did not include any general surgeons.

Legislation, quality and safety considerations

ISO accreditation, safety, referral guidelines and adherence to EU legislation had a high level of agreement (statements 19, 25, 26, 41 all with a median of 6.0) and the highest level of consensus (IQR of 0.5, 0.5, 0.0 and 0.0 resp.). Referral guidelines on making the best use of an MRI Department should be available and if used appropriately would reduce waiting times.[45,46] Picano[47] notes that a third of radiological investigations are totally or partially inappropriate and suggests that referrers should be required to have a radiological driving licence: "*I think in the right context there is an important role for non MD referrals typically what comes to mind is referrals by physiotherapists and general practitioners however I say this with a degree of apprehensiveness*" (Radiologist).

Accessibility for patients and non-medical referrers

Participants reported that if the education of non-MD professionals becomes broader then there is the possibility that certain routine examinations such as lumbar MRI could be requested by non-MD: "*Specialized nurses could request MRI spine…. if you have someone who spends two years in this field he/she will eventually learn who requires an MRI and who doesn't …*" (Neurosurgeon). MRI referral by non-physicians such as extended scope physiotherapists is now becoming more common[48,49] and recent studies have shown that with higher education non-MD practitioners can be cost effective whilst making the best use of MRI scanners.[48,50,51] However, there was low consensus among participants on whether all referrers should be certified in MRI education before being granted referral privileges (22, 5.0, 1.5). The non-MD experts in the panel reiterated that although health care practice in Malta is moving in this direction, more education is required and the establishment of evidence based referral criteria is a must (27, 6.0, 1.0). Participants were of the impression that although at the local general hospital only consultant clinicians are permitted to request MRIs, in reality the requesting privileges were often delegated to junior doctors "*Well I am under the impression it should be the consultant clinicians but I am also aware that this privilege is often delegated to junior doctors. I am not sure whether this is good practice but I am told that it is allowed in our institution and basically this does give rise to some confusion*" (Radiologist). In the private setting the mix of referrers is dictated by private insurance schemes. By default, insurance policy dictates that MRI scans be referred by a consultant; as a result 70% of the requests in the private setting originate from consultants. On the other hand in the case of self-funded patients 15% are referred by general practitioners, 10% by non-MD and 5% are self-referred. The latter category of patients is still required to be seen by a consultant radiologist attending at a private clinic. Self-referrals are not accepted at the local general hospital even though participants commented that they do meet patients who demand MRI scans. Although MRI accessibility has improved there seem to be differences in referral policies between states. An Italian study suggests that MRI can be requested by general practitioners; in Australia, accessibility has been made available to general practitioners. Perhaps widening further the accessibility to MRI at the local general hospital and private setting to general practitioners would alleviate the waiting time if referral guidelines are implemented and quality education to general practitioners implemented.[52,53]

The majority of participants working at the local public hospital agreed that outsourcing should only be considered after all available options have been exhausted. Experts reported that from experience outsourcing does not necessarily need to control over costs, customer satisfaction and assurance of quality and standards of care. It was also mentioned that outsourcing should only be considered if the financial implications are advantageous with respect to buying a further magnet at the public hospital. Experts from the private sector have reported that their institutions are well placed to address the increasing requests through private-public partnership. This difference between experts working in the public hospital and those coming from the private sector was manifested in the low level of consensus (16, 5.0, 2.0).

Retired services

The participants agreed that no service from the current list of available procedures should be sidelined (42, 6.0. 1.0). One participant however commented with some caution that shoulder MRI imaging is expected to decrease as ultrasound takes over. *'Shoulder ultrasound is operator dependent as well. I don't think we could do without MRI although I think that if we excel in ultrasound we could reduce MR shoulder request'* (Orthopaedic surgeon). The fact that no services are expected to decrease has operational implications to radiographer managers as they address increase in demands and waiting lists. As a direct result of this research the public hospital in Malta has successfully introduced twilight initiatives whereby extra MRI sessions are carried out during the night (9:00pm and 2:00am) and very early in the morning (5:00am till 7:00am). In addition to this the hospital administration has procured another MRI magnet which will be installed in November 2014 and started discussions to upgrade the current magnet. Ministry for Health also signed a limited public private partnership scheme whereby some patients could be scanned in the private health sector.

Strengths and weakness of the study

A qualitative methodology involving experts from different backgrounds was employed using MRI as an exemplar for many other imaging modalities. The study involved a relatively small but usual number of participants which were purposely selected for a Delphi technique. The sample did not include general surgeons because at the time of the study requests from this group of referrers were low. The exclusion of this group was a limitation of this study, but which was however minimised by the inclusion of radiologists. Caution is therefore required in generalising the results to other hospitals or similar imaging modalities.

There is an absence of research concerning the development of service portfolio for Magnetic Resonance Imaging Departments and this study offers guidance to management of medical imaging services. Although Delphi studies are time consuming, specifically when the instrument of a Delphi study consists of a large number of statements, electronic technology (web based questionnaires as used in this study) provides an opportunity for managers to more easily employ the Delphi process by taking advantages of the storage, processing, speed of transmission capabilities of computers, the potential for rapid feedback and analysis.[19,33] Delphi study is useful for long term forecasting and so it is not expected to be used frequently by medical imaging managers. However managers utilizing this method of consensus would require research skills specifically qualitative analysis.[23]

Conclusion

This study has proposed a research based methodology for the development of a proposed MRI service portfolio for Malta which avoids the potential pitfalls of low relevance to local healthcare needs and/or subjectivity of other methods presently in use. The results highlight important current issues related to research and education, ISO certification of MRI quality and safety, the development of MRI referral guidelines and the updating of local MRI policies and procedures with respect to EU legislation. The study has given the necessary background to introduce new initiatives. The authors believe that this is the first published article concerning a systematic approach to forecasting an MRI service portfolio.

Conflict of interest

None.

References

1. Joyce KA. *Magnetic appeal: MRI and the myth of transparency*. Cornell University Press; 2008.

2. Agarwal R, Bergey M, Sonnad S, Butowsky H, Bhargavan M, Bleshman MH. Inpatient CT and MRI utilization: trends in the academic hospital setting. *J Am Coll Radiol* 2010;**7**(12):949–55.
3. Mitchell JM. Utilization trends for advanced imaging procedures: evidence from individuals with private insurance coverage in California. *Med Care* 2008;**46**(5):460–6. http://dx.doi.org/10.1097/MLR.0b013e31815dc5ae.
4. Sommer CA, Stitzenberg KB, Tolleson-Rinehart S, Carpenter WR, Carey TS. Breast MRI utilization in older patients with newly diagnosed breast cancer. *J Surg Res* 2011;**170**(1):77–83.
5. OECD/European Union. *Medical technologies: CT scanners and MRI units in health at a glance: Europe 2010*. 2010.
6. Times of Malta. *MRI scan waiting list: 3,531*. Times of Malta; 2013.
7. Times of Malta. *Waiting lists*. Times of Malta; 2008.
8. Castillo J, Caruana CJ. Maltese radiographers' attitudes towards continuing professional development: an initial study using concept maps. *J Med Imaging Radiat Sci* 2013;**45**(1):37–46.
9. Markwell S. *Health service development and planning*. 2009.
10. World Health Organization. *Quality of care: a process for making strategic choices in health systems*. 2006.
11. Tomlinson P, Hewitt S, Blackshaw N. Joining up health and planning: how Joint Strategic Needs Assessment (JSNA) can inform health and wellbeing strategies and spatial planning. *Perspect Public Health* 2013;**133**(5):254–62.
12. Wennberg J, Gittelsohn A. Small area variations in health care delivery a population-based health information system can guide planning and regulatory decision-making. *Science* 1973;**182**(4117):1102–8.
13. Wennberg JE. Unwarranted variations in healthcare delivery: implications for academic medical centres. *BMJ – Br Med J* 2002;**325**(7370):961.
14. Stagnitti K, Schoo A, Reid C, Dunbar J. Access and attitude of rural allied health professionals to CPD and training. *Int J Ther Rehabil* 2005;**12**(8):355–62.
15. Brailsford S, Vissers J. OR in healthcare: a European perspective. *Eur J Oper Res* 2011;**212**(2):223–34.
16. Marquis H. *A study guide to service catalogue from the principles of Itil V3*, vol. 3; 2010. TSO Shop.
17. Linstone HA, Turoff M, Helmer O. *The Delphi method: techniques and applications*. Addison-Wesley Publishing Company, Advanced Book Program; 1975.
18. Franklin KK, Hart JK. Idea generation and exploration: benefits and limitations of the policy Delphi research method. *Innov High Educ* 2007;**31**(4):237–46.
19. Okoli C, Pawlowski SD. The Delphi method as a research tool: an example, design considerations and applications. *Inf Manag* 2004;**42**(1):15–29.
20. Gillham B. *Research interviewing: the range of techniques*. Open University Press; 2005.
21. Keeney S, McKenna H, Hasson F. *The Delphi technique in nursing and health research*. Wiley-Blackwell; 2011.
22. Keeney S, Hasson F, McKenna H. Consulting the oracle: ten lessons from using the Delphi technique in nursing research. *J Adv Nurs* 2006;**53**(2):205–12.
23. Hasson F, Keeney S, McKenna H. Research guidelines for the Delphi survey technique. *J Adv Nurs* 2000;**32**(4):1008–15.
24. von der Gracht HA. Consensus measurement in Delphi studies: review and implications for future quality assurance. *Technol Forecast Soc Change* 2012;**79**(8):1525–36.
25. Rayens MK, Hahn EJ. Building consensus using the policy Delphi method. Policy, politics. *Nurs Pract* 2000;**1**(4):308–15.
26. Gill P, Stewart K, Treasure E, Chadwick B. Methods of data collection in qualitative research: interviews and focus groups. *Br Dent J* 2008;**204**(6):291–5.
27. Berg BL. *Qualitative research methods for the social sciences*. 2001.
28. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol* 2006;**3**(2):77–101.
29. [cited 2013 4th December] *Institute for Human and Machine Cognition. CMAP-TOOLS*. 2010. Available from:, http://IHMC.US/cmaptools.php.
30. Novak JD, Cañas AJ. *The theory underlying concept maps and how to construct and use them. Florida Institute for Human and Machine Cognition Pensacola Fl.* 2008. http://cmap.ihmc.us/publications/researchpapers/theorycmaps/theoryunderlyingconceptmaps.htm.
31. Beaudin BP. Keeping online asynchronous discussions on topic. *J Asynchronous Learn Netw* 1999;**3**(2):41–53.
32. Crisp J, Pelletier D, Duffield C, Adams A, Nagy S. The Delphi method? *Nurs Res* Mar–Apr 1997;**46**(2):116–8.
33. Hsu C-C, Sandford BA. The Delphi technique: making sense of consensus. *Pract Assess Res Eval* 2007;**12**(10):1–8.
34. Shaikh MZA. Validating teachers' competence for personal learning environments: a Delphi study. In: *3rd International Conference for e-learning and Distance Education*; 2013. Riyadh.
35. European Society of Radiology. *Alliance for MRI – news*. 2013 [cited 2013 December 11th], Available from: http://www.myesr.org/cms/website.php?id=/en/eu_affairs_research/alliance_for_mri/alliance_for_mri_-_news.htm.
36. Saunders DE, Thompson C, Gunny R, Jones R, Cox T, Chong WK. Magnetic resonance imaging protocols for paediatric neuroradiology. *Pediatr Radiol* 2007;**37**(8):789–97.
37. McRobbie DW. *MRI from picture to proton*. Cambridge University Press; 2007.
38. Kanal E, Borgstede JP, Barkovich AJ, et al. American College of Radiology white paper on MR safety: 2004 update and revisions. *Am J Roentgenol* 2004;**182**(5):1111–4.
39. Choyke PL, Turkbey B. *The state of prostate MRI in 2013: into the breach*. UBM Medica 535 Connecticut Ave; 2013. Ste 300, Norwalk, CT 06854 USA.
40. Li X, Priest RA, Woodward WJ, et al. Feasibility of shutter-speed DCE-MRI for improved prostate cancer detection. *Magn Reson Med* 2013;**69**(1):171–8.
41. Gupta RT, Kauffman CR, Polascik TJ, Taneja SS, Rosenkrantz AB. The state of prostate MRI in 2013. *Oncology* 2013;**27**(4):1.
42. Kirkham A, Haslam P, Keanie J, et al. Prostate MRI: who, when, and how? Report from a UK consensus meeting. *Clin Radiol* 2013;**68**(10):1016–23.
43. Tanimoto A, Nakashima J, Kohno H, Shinmoto H, Kuribayashi S. Prostate cancer screening: the clinical value of diffusion-weighted imaging and dynamic MR imaging in combination with T2-weighted imaging. *J Magn Reson Imaging* 2007;**25**(1):146–52.
44. Ahmed HU, Kirkham A, Arya M, et al. Is it time to consider a role for MRI before prostate biopsy? *Nat Rev Clin Oncol* 2009;**6**(4):197–206.
45. Commission, E. *Radiation protection 118: referral guidelines for imaging*. Luxembourg: Office for Official Publications of the European Communities; 2001.
46. *RCR, making the best use of a department of clinical radiology: guidelines for doctors*. 2003.
47. Picano E. Sustainability of medical imaging. *BMJ – Br Med J* 2004;**328**(7439):578.
48. Inman D, Leaver A, Gage D, Miering PDV. An evaluation of physiotherapy extended scope practitioner (esp) use of MRI in patients presenting with low back pain; a two-centre study. British Volume *J Bone Jt Surg* 2009;**91**(Supp. III). 487–487.
49. Newsome RJ, Reddington M, Breakwell LM, Chiverton N, Cole AA, Michael A. Measuring competencies within the orthopaedic spinal service; MRI requesting rights by spinal extended scope physiotherapists within secondary care one year on. British Volume *J Bone Jt Surg* June 1, 2012;**94-B**(Supp. XXVI). 84.
50. Locke M. *Physiotherapy patient referral to SEM physicians under the medicare benefits schedule*. 2011.
51. Shannak O, Dahabreh Z, Gonsalves S, Philipson MR, Calder SJ. The efficacy of a physiotherapy led acute knee injury clinic at Leeds General Infirmary. British Volume *J Bone Jt Surg* June 1, 2010;**92-B**(Supp. III). 423.
52. Bradfield OM. GP access to MRI: the Australian reality. *Aust Health Rev* 2009;**33**(2):311–4.
53. Simpson GC, Forbes K, Teasdale E, Tyagi A, Santosh C. Impact of GP direct-access computerised tomography for the investigation of chronic daily headache. *Br J General Pract* 2010;**60**(581):897.

Please cite this article in press as: Castillo J, et al., Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020, Radiography (2014), http://dx.doi.org/10.1016/j.radi.2014.09.003

Radiography xxx (2014) 1–5

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Optimizing a magnetic resonance care pathway: A strategy for radiography managers

J. Castillo [a,*], C.J. Caruana [b], P.S. Morgan [c], C. Westbrook [d]

[a] Mater Dei Hospital and Faculty of Health Sciences, University of Malta, Malta
[b] Medical Physics, Faculty of Health Sciences, University of Malta, Malta
[c] Medical Physics and Clinical Engineering, Nottingham University Hospitals, Nottingham NG7 2UH, UK
[d] Faculty of Health, Social Care and Education, Anglia Ruskin University, Cambridge, UK

A R T I C L E I N F O

Article history:
Received 2 April 2014
Received in revised form
6 September 2014
Accepted 9 September 2014
Available online xxx

Keywords:
Nominal group technique
Radiography
Management
MRI care
Pathway

A B S T R A C T

Purpose: This study reports the optimization of a local MR care pathway. A search of the literature did not result in any studies regarding the optimization of MRI care pathways through a formal research process. Discussions with international MR radiographers indicated that such development is often carried out using informal methods that are highly dependent on local conditions, that are rarely reported in the public domain and the validities of which are therefore not open to scrutiny; in addition, care pathways need to be specific to local healthcare needs and culture. In this study, the authors propose a formal documented methodology for developing a local MRI care pathway based on the well-established nominal group technique.

Methods and materials: A nominal group technique was conducted amongst a multi-professional panel.

Results: 14 participants accepted the invitation to participate: an executive from the principal public general hospital, a manager from the national Ministry for Health, a service development manager from the allied healthcare professional sector, 2 senior physiotherapists, 3 nursing officers, 3 MRI radiographers, 2 medical physicists, 1 radiologist. Ten optimization related issues were identified and ranked in order of decreasing importance. Highest ranking scores were assigned to patient safety, education of referrers and use of quality criteria. The NGT method also brought forward novel themes in particular the need for a radiographer's technical report and the need for referrers to indicate pain levels of patients.

Conclusion: The design of an MR care pathway was successfully optimized using a collaborative multi-stakeholder approach.

Introduction

At the MRI unit level, service quality is contingent on the design of the care pathway through which the MRI service is delivered and experienced by patients.[1,2] Hence, an optimized care pathway design is crucial for the attainment of an effective, safe and efficient service.[3] This study reports the optimization of such a local care pathway as initially perceived and developed by the researchers and based on input from local and international colleagues. A search of the literature did not result in any studies regarding the optimization of MRI care pathways through a formal research process. Discussions with international MR radiographers indicated that such development is often carried out using informal methods that are highly dependent on local conditions, that are rarely reported in the public domain and the validities of which are therefore not open to scrutiny; in addition, care pathways need to be specific to local healthcare needs and culture. In this study, the authors propose a formal documented methodology for developing a local MRI care pathway based on the well-established nominal group technique (NGT). The study forms part of a wider study on continuous professional development for senior radiographers in Malta; the optimized pathway will provide input to curriculum development.

* Corresponding author. Tel.: +356 25456773.
E-mail addresses: joseph.castillo@gov.mt (J. Castillo), carmel.j.caruana@um.edu.mt (C.J. Caruana), paul.morgan@nottingham.ac.uk (P.S. Morgan), Catherine.westbrook@anglia.ac.uk (C. Westbrook).

http://dx.doi.org/10.1016/j.radi.2014.09.002
1078-8174/

Please cite this article in press as: Castillo J, et al., Optimizing a magnetic resonance care pathway: A strategy for radiography managers, Radiography (2014), http://dx.doi.org/10.1016/j.radi.2014.09.002

The European Pathway Association (http://www.e-p-a.org) defines a care pathway as: "A complex intervention for the mutual decision making and organization of predictable care for a well-defined group of patients during a well-defined period. Defining characteristics of pathways include: an explicit statement of the goals and key elements of care based on evidence, best practice and patient expectations; the facilitations of the communication and coordination of roles, and sequencing the activities of the multidisciplinary care team, patients and their relatives; the documentation, monitoring, and evaluation of variances and outcomes; and the identification of relevant resources". This study focuses on the "the facilitations of the communication and coordination of roles, and sequencing the activities of the multidisciplinary care team". The design of clinical care pathways combines a variety of methods from the quality improvement and operational research literature. Such literature indicates that a critical characteristic to consider with respect to the sequencing of activities of the multidisciplinary care team is the coordination model required. Vanhaecht et al.[4] describe three different coordination models: chain, hub and web models. Chain models are used for relatively highly predictable care processes with a high level of agreement between the team members. Hub models are used for less predictable processes; in this model key persons will lead the organization of the care process and chain models are used for the more predictable sub-processes. Web models are used for highly unpredictable, complex processes.[4] Diagnostic radiology would fit the hub model whilst the MRI care pathway sub-process fits a chain model which permits elements of flexibility as where practice involves a mix of routine and non-routine tasks (as in an MRI setting), employees need to be able to take initiatives in response to incidental findings or to optimize processes beyond the confines of standard operating procedures.[5]

Table 1
The NGT method used in the study.

Step	Comment
1. Introductory statement	The initial care pathway model was projected on a screen and participants requested to confirm or otherwise whether it was suitable to kickstart the process or whether a major modification was required. A set of guiding questions was also presented.
2. Initial generation of issues individually	Participants were asked to silently list issues on the paper provided.
3. Round-robin listing of ideas	The participants were asked to articulate briefly each issue until all issues were exhausted. Issues were recorded on a flip-chart.
4. Clarification of issues	The group was then asked to consider each item on the list to ensure common understanding. No items were omitted or merged so that all ideas were given their due importance.[13]
5. Generation of individual top 10 lists	The participants were asked to individually select and prioritize the 10 issues that they felt were most important and record them on a worksheet.
6. Rating of issues according to relative importance	The worksheets were collected, and the issues and rankings noted.
7. Time out and icebreaker	The rankings for each individual issue were summed to give a total score.
8. Group discuss of most important issues	The top 15 issues were presented to the group for discussion with the facilitator only intervening to ensure focus. These were condensed to 10 issues.
9. Final ranking of issues	Participants were asked to individually rank the 10 issues in order of importance. This time the participants assigned a weighting to each item, with the most important issue receiving a weighting of 100 and the least important a weighting of 1. The eight remaining issues were given a weighting between 1 and 100.
10. Conclusion	The final list of 10 ranked issues was presented for final discussion. Participants were thanked for their participation and subsequently informed of the findings.

Method

Various techniques for the development of the care pathway were considered. A survey of the literature revealed that multi-stakeholder processes require consensus techniques such as the Delphi, nominal group or focus group techniques.[6–8] Four important practical issues were taken into consideration before deciding on the most appropriate technique to use: the approach needed to involve as many of the MRI stakeholders as possible, it needed to be based on a consensus building approach, it needed to ensure that all participants could voice their opinions freely, and finally be efficient in terms of time. These are the defining characteristics and strengths of the NGT technique. NGT methods gather a number of specifically invited experts, commonly 10–15, for a structured meeting on a specific subject.[9] The purpose of the NGT technique is to generate ideas, which are then discussed and ranked by the group.[10] The group is highly controlled, with discussion occurring only in the later stages of the process. A facilitator guides and controls the meeting by collecting ideas from participants, as opposed to leading the discussion.[11] The work of the facilitator is usually complemented by one or two other individuals acting as note-takers and co-ordinators of activities. The technique aims to avoid the known pitfalls of group interviews where some participants can be silent or feel intimidated in the presence of more articulate and dominant personalities. In NGT all members have an equal opportunity to contribute.[11] The nominal group technique as described by Wainwright et al.[12] was adopted for this study. To kickstart the process an initial model of the MR care pathway for adults was developed by the researchers with the help of a small multidisciplinary group consisting of an MRI radiographer, radiologist and medical physicist and forwarded to the invited participants. This ensured that the participants focus on the actual pathway during the NGT process proper. The NGT method used in this study is summarized in Table 1. The process in this study took approximately 2 h and generated quantitative rankings of key optimization related issues.

17 participants, representing radiologists, radiographers, management, medical physicists, policy makers, physiotherapists and nurses working in orthopaedics, neurosurgery and neurology were selected. The intention was to create a balanced representation of expertise from various sectors of professionals working in collaboration. Ideally the group of participants should also have included patient representatives. Unfortunately patient associations are still very much in their infancy in Malta, hence nurses who have themselves been MRI patients or had close family members referred for MRI were chosen to act as patient advocates. This had the added advantage that bias resulting from power inequalities between patients and healthcare professionals was avoided.[14] Since conduction of the NGT session in a clinical setting may influence participant responses, the session was carried out at a leading hotel. The process was recorded and transcribed verbatim to ensure that no data were lost and to provide a documented record of the proceedings. Ethical approval was received from the ethics committee of the University of Malta. All participants were provided with information regarding the study and consent was obtained before the start of the NGT.

Please cite this article in press as: Castillo J, et al., Optimizing a magnetic resonance care pathway: A strategy for radiography managers, Radiography (2014), http://dx.doi.org/10.1016/j.radi.2014.09.002

Table 2
Final ranking of the ten most important care pathway optimization related issues as determined by the participants.

Rank	Items	Remarks	Ranking score
1	Safety check at referral stage.	This will ensure that any contraindications related to metallic implants are resolved at an early stage hence eliminating delays on the day of the exam proper.[15] Psychological issues that may affect the procedure are brought to the attention of the MRI radiography team in advance.[16,17] This would permit specific anxiety reduction protocols to be employed.	80
2	Education of referrers	MRI education of referring clinicians is necessary to avoid inappropriate requests and efficient use of MR facilities.[18,19]	78
3	Establish pre-determined objective quality criteria for evaluation and monitoring at critical stages of the care pathway	Clinical criteria are a standard process adopted by all health care organizations that espouse the principles of continuous quality improvement.[20–22]	77
4	Define in terms of effectiveness, safety and efficiency the meaning of 'quality' for each sub-process of the care pathway.	This would ensure that patients receive effective care, in good time and at fair cost.[23] This should really be a precursor to issue 3.	76
5	Early explanation of the procedure to the patient before coming to MRI	An early explanation of the procedure to alleviate anxiety, and identify in advance those patients with claustrophobia is very important.[24,25]	69
6	Establish local referral guidelines (appropriateness criteria)	Referral guidelines to assist the referring clinician in choosing the best imaging modality. This issue is a precursor to issue 2.[19,26,27]	66
7	Transparent prioritization guidelines	Transparent prioritization guidelines to ensure urgent cases are scheduled earlier and non-urgent cases are prioritized fairly and in a transparent manner. System must be transparent so that clinicians will not hinder its implementation and so that patients feel that they have been respected.[28]	65
8	Knowledge of the care pathway by all stakeholders	This would ensure that the care pathway is accepted by all stakeholders and that any subsequent modifications are well understood and accepted by the various stakeholders.[29]	55
9	Patient satisfaction surveys	Patient satisfaction surveys are today considered as an indispensable tool to provide client feedback for further improvement of service quality.[30,31]	50
10	Urgency criteria for diagnostic results following the scan (flagging)	In particular critical incidental findings need to be brought to attention of referring clinicians immediately.[32,33]	37

Results

14 participants accepted the invitation to participate: an executive from the principal public general hospital, a manager from the national Ministry for Health, a service development manager from the allied healthcare professional sector, 2 senior physiotherapists, 3 nursing officers, 3 MRI radiographers, 2 medical physicists, 1 radiologist. The final ten optimization related issues in order of decreasing importance as determined by the ranking scores assigned by the participants are shown in Table 2.

The group gave a strong affirmative answer when asked if the model as presented by the researchers with the additional 10 issues identified through the NGT was sufficient to form the basis of the desired future MR care pathway. The resulting MR care pathway is shown in Fig. 1. The pathway shows the patient's journey from when he/she is referred for an MRI scan up to the follow-up visit to the referrer. The numbers in brackets (1–10) in the diagram refer to the NGT identified issues from Table 2 relevant to that particular section of the pathway. The pathway is divided into various sub-processes at which defined quality outcomes (indicated with an 'O' in the diagram) and associated criteria would need to be inserted.

The following additional suggestions gleaned from the verbatim transcript of the session and which would add further support for the main issues of Table 2 were also incorporated into the care pathway (indicated as (a)–(e) in the diagram):

a) Need for a mechanism to audit the appropriateness of referrals. *"We need to answer the question: has the investigation had an effect on patient management? We are all aware of the high percentage of patients being referred simply because the referrer has no other option – patients insist on an MRI even on occasions when the referrer thinks it is inappropriate"*
b) Need to educate radiographers on procedures to follow following incidental findings: *"although there is an electronic feedback mechanism linking radiographers and radiologists this is not always being utilized owing to the large throughput"*
c) Importance of the introduction of a radiographers' technical report: *"Radiographers should issue a written technical report in which they confirm that the quality of the images was sufficient for diagnosis, and that safety criteria have been met and to record any variance from the original care plan. This technical report would form the basis for audits…"*
d) The use of social electronic media: *"We should use social electronic media for providing early explanation to patients on what to expect during an MRI scan using social electronic media"*
e) The importance that the referrer qualifies pain levels of patients: *"The referrer should qualify the region and level of pain that the patient may be experiencing. This information would be useful for radiographers to plan the procedure so that the most important sequences are acquired first in relation to the clinical question"*

Discussion

The MR care pathway describes the tasks performed by the various members of the healthcare team and their interactions with each other and the patient. The aim is to achieve the desired defined quality outcomes at the various sections of the pathway. The group highlighted 10 issues that should be integrated into the initially proposed care pathway. These are listed in order of decreasing importance in Table 2. The 'remarks' column in the same table provides further explanation and discussion relative to the literature. It is welcoming to note the importance given by the participants to patient safety, education of referrers and use of quality criteria. The group has identified the importance of involving the referrers at an early stage, insisting that the latter are knowledgeable about the care pathway, and that they have access

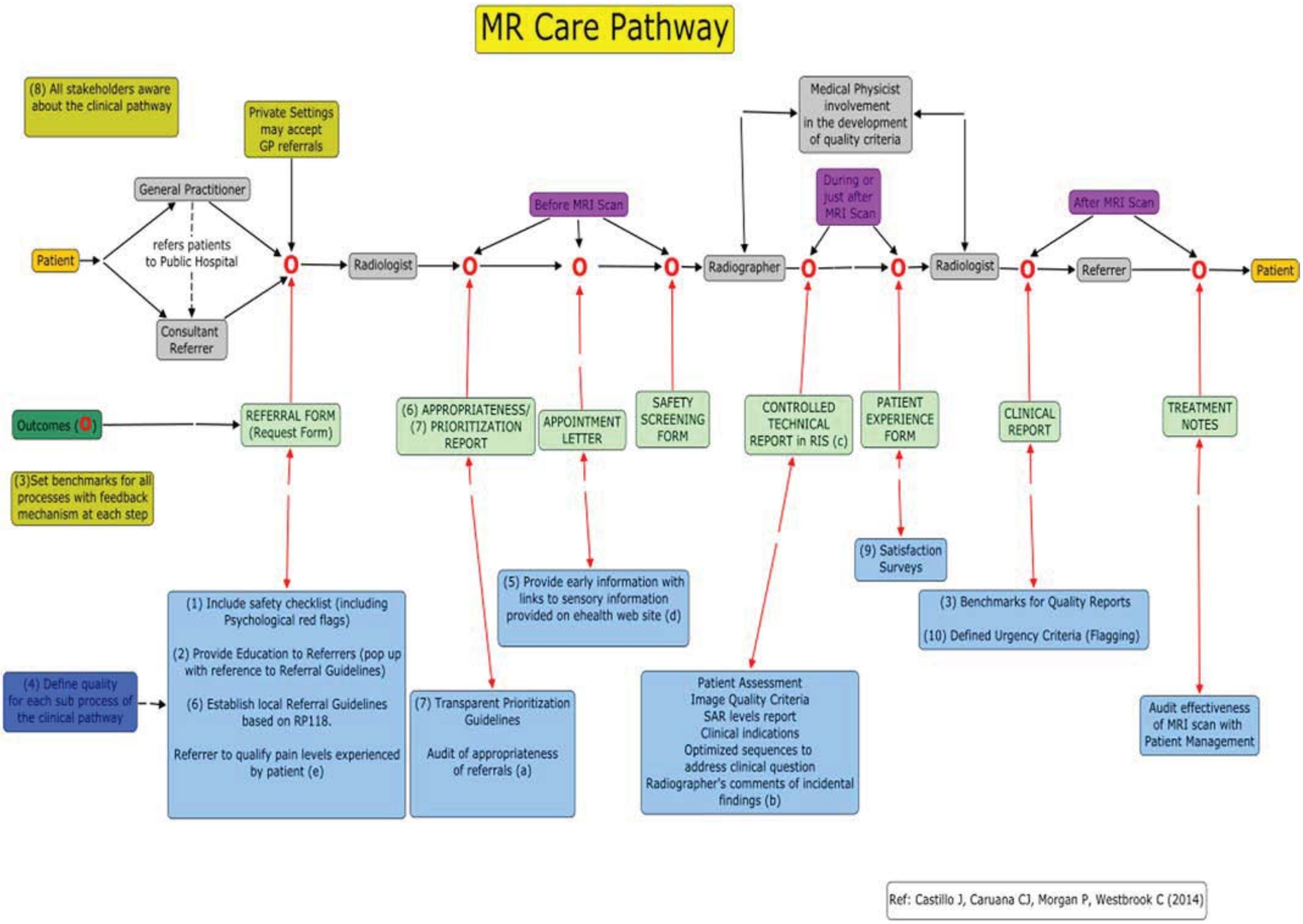


Figure 1. Final MRI care pathway.

to transparent prioritization guidelines. This would reduce individual barriers to the implementation of the pathway.[29]

Two important issues are the importance of referral and quality criteria. The Institute of Medicine round table on quality of care referred to underuse, overuse and misuse of care as safety threats to patients at both the individual and collective level.[34] Only when compilation, disclosure and evaluation of safety and quality indicators with respect to previously established quality criteria, will the quality of clinical practices be improved.[35] In addition, evaluation should focus not only on end clinical outcomes but also on intermediate sub-processes[36,37] as proposed in this study. It is envisaged that audit tools in the form of checklists will be developed to evaluate key intermediate sub-process outcomes (marked with an 'O' in the diagram) that have major impact on end patient outcomes.[38]

The NGT raised issues that were novel. Most importantly for the radiography profession, the group suggested the introduction of a technical report by radiographers that together with the radiologist diagnostic report would provide a more complete documentation to the referrer and to management. This would certainly facilitate the successful implementation of the pathway.[39,40]

Another novel theme raised by the patient advocates was the importance of referrers indicating the level of pain experienced by patients. This would permit radiographers to plan a safer and more comfortable procedure for patients. This important suggestion highlights the capacity of healthcare professionals to act on behalf of patients, and the strength of the NGT method in bringing forth previously unknown issues.

Prior information on the MRI procedure for patients should make better use of interactive information technology. Information about what patients should expect during an MRI procedure would be an effective way of improving the workflow and quality of the service. Although such information is not as widely available as is desirable, social media are already being used by patients to liaise with medical practitioners and acquire timely information.[41] In addition, web based clinical decision support systems could assist referring clinicians with respect to referral criteria.[27,42]

The production of a prioritized list of issues may be seen as a limitation given that the method involved focusing only on the top 10 issues and setting aside those of lower priority. However, this limitation was addressed by asking all participants to silently generate their own list of issues and thus ensure that all issues have an equal probability of being placed on the discussion agenda. This procedure avoided significant risk of loss of important data when more assertive members of the group dominate effectively excluding the views of others. One can expect a high level of confidence that the group listed the most important items that should be integrated in the pathway. In addition, the process of selection and prioritization ensured that the issues which were most important to the participants received the highest level of attention. Without this mechanism, there would have been the risk that the discussion be dominated by one or two contentious issues.

Conclusion

This study started from a model of the MR pathway as perceived by the researchers. The pathway was then optimized through a nominal group technique. Care pathways are widely believed to be an important tool for ensuring the delivery of high quality, evidence-based care. This paper has presented one example where stakeholders with an interest in MRI and service development have come together to optimize an MRI care pathway collaboratively. The findings indicate that participants attached the highest importance (rank score >70) to safety, referrer education and defining quality criteria. The NGT method also brought forward novel themes in particular the need for a radiographer's technical report and the need for referrers to indicate pain levels of patients. MRI radiographers in Malta now would need to acquire the additional knowledge, skills and competences required to deliver the care pathway through a CPD programme with curriculum content partly based on the care pathway identified in this study. The pathway is considered as a living document, once the MRI radiographers are adequately prepared through CPD it will be implemented, evaluated and if necessary revised in an iterative process.

Conflict of interest statement

None.

References

1. Johnston R, Clark G. *Service operations management: improving service delivery*. Pearson Education; 2005.
2. Yazdanparast A, Manuj I, Swartz SM. Co-creating logistics value: a service-dominant logic perspective. *Int J Logist Manag* 2010;**21**(3):375–403.
3. Cheah J. Development and implementation of a clinical pathway programme in an acute care general hospital in Singapore. *Int J Qual Health Care.* 2000;**12**(5):403–12.
4. Vanhaecht K, Panella M, Van Zelm R, Sermeus W. An overview on the history and concept of care pathways as complex interventions. *Int J Care Pathw* 2010;**14**(3):117–23.
5. Ponsignon F, Smart P, Maull R. Service delivery system design: characteristics and contingencies. *Int J Oper Prod Manag* 2011;**31**(3):324–49.
6. Jones J, Hunter D. Consensus methods for medical and health services research. *Br Med J* 1995;**311**(7001):376.
7. Hutchings A, Raine R, Sanderson C, Black N. A comparison of formal consensus methods used for developing clinical guidelines. *J Health Serv Res Policy* 2006;**11**(4):218–24.
8. Kitzinger J. Qualitative research. Introducing focus groups. *Br Med J* 1995;**311**(7000):299.
9. Fink A, Kosecoff J, Chassin M, Brook RH. Consensus methods: characteristics and guidelines for use. *Am J Public Health* 1984;**74**(9):979–83.
10. Delbecq AL, Van de Ven AH, Gustafson DH. *Group techniques for program planning: a guide to nominal group and Delphi processes*. Glenview, IL: Scott, Foresman; 1975.
11. Potter M, Gordon S, Hamer P. The nominal group technique: a useful consensus methodology in physiotherapy research. *N Z J Physiother* 2004;**32**(3).
12. Wainwright D, Boichat C, McCracken LM. Using the nominal group technique to engage people with chronic pain in health service development. *Int J Health Plan Manag* 2013;**29**(1):52–69.
13. Steward B. Using nominal group technique to explore competence in occupational therapy and physiotherapy students during first-year placements. *Br J Occup Ther* 2001;**64**(6):298–304.
14. Vaartio-Rajalin H, Leino-Kilpi H. Nurses as patient advocates in oncology care. *Clin J Oncol Nurs* 2011;**15**(5):526–32.
15. Ferris NJ, Kavnoudias H, Thiel C, Stuckey S. The 2005 Australian MRI safety survey. *Am J Roentgenol* 2007;**188**(5):1388–94.
16. Törnqvist E, Månsson Å, Larsson EM, Hallström I. It's like being in another world–patients' lived experience of magnetic resonance imaging. *J Clin Nurs* 2006;**15**(8):954–61.
17. Grey SJ, Price G, Mathews A. Reduction of anxiety during MR imaging: a controlled trial. *Magn Reson Imaging* 2000;**18**(3):351–5.
18. Blachar A, Tal S, Mandel A, Novikov I, Polliack G, Sosna J, et al. Preauthorization of CT and MRI examinations: assessment of a managed care preauthorization program based on the ACR appropriateness criteria® and the Royal College of Radiology Guidelines. *J Am Coll Radiol* 2006;**3**(11):851–9.
19. Lehnert BE, Bree RL. Analysis of appropriateness of outpatient CT and MRI referred from primary care clinics at an academic medical center: how critical is the need for improved decision support? *J Am Coll Radiol* 2010;**7**(3):192–7.
20. Busch HP. Benchmarking of radiological departments–starting point for successful process optimization. *RoFo Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin.* 2010;**182**(3):221–8.
21. Barnes R, Lawton L, Briggs D. Clinical benchmarking improves clinical paths: experience with coronary artery bypass grafting. *Jt Comm J Qual Improv* 1994;**20**(5):267–76.
22. European Society of Radiology. Benchmarking radiological services in Europe. http://myesr.org/html/img/pool/Benchmarking_radiological_services_in_Europe.pdf.
23. Campbell SM, Roland MO, Buetow SA. Defining quality of care. *Soc Sci Med* 2000;**51**(11):1611–25.
24. Bolejko A, Sarvik C, Hagell P, Brinck A. Meeting patient information needs before magnetic resonance imaging: development and evaluation of an information booklet. *J Radiol Nurs* 2008;**27**(3):96–102.
25. MacKenzie R, Sims C, Owens R, Dixon A. Patients' perceptions of magnetic resonance imaging. *Clin Radiol* 1995;**50**(3):137–43.
26. Blackmore CC, Mecklenburg RS, Kaplan GS. Effectiveness of clinical decision support in controlling inappropriate imaging. *J Am Coll Radiol* 2011;**8**(1):19–25.
27. Rosenthal DI, Weilburg JB, Schultz T, Miller JC, Nixon V, Dreyer KJ, et al. Radiology order entry with decision support: initial clinical experience. *J Am Coll Radiol* 2006;**3**(10):799–806.
28. Emery DJ, Forster AJ, Shojania KG, Magnan S, Tubman M, Feasby TE. Management of MRI wait lists in Canada. *Healthc Policy.* 2009;**4**(3):76.
29. Evans-Lacko S, Jarrett M, McCrone P, Thornicroft G. Facilitators and barriers to implementing clinical care pathways. *BMC Health Serv Res* 2010;**10**(1):182.
30. Nelson CW, Niederberger J. Patient satisfaction surveys: an opportunity for total quality improvement. *Hosp Health Serv Adm* 1989;**35**(3):409–27.
31. Ware GW. Patient satisfaction surveys. *Optometry (St Louis)* 2003;**74**(10):671–2.
32. Singh H, Arora HS, Vij MS, Rao R, Khan MM, Petersen LA. Communication outcomes of critical imaging results in a computerized notification system. *J Am Med Inform Assoc* 2007;**14**(4):459–66.
33. Ferris TG, Johnson SA, Backus M, Perrin J, Bates DW, Poon EG. Electronic results management in pediatric ambulatory care: qualitative assessment. *Pediatrics* 2009;**123**(Supplement 2):S85–91.
34. Institute of Medicine. *Crossing the quality chasm: a new health system for the 21st century*. National Academies Press; 2001.
35. Corrigan JM. *Crossing the quality chasm. Build a better delivery system.* 2005.
36. Curtis JR, Cook DJ, Wall RJ, Angus DC, Bion J, Kacmarek R, et al. Intensive care unit quality improvement: a "how-to" guide for the interdisciplinary team*. *Crit care Med* 2006;**34**(1):211–8.
37. Von Korff M, Goldberg D. Improving outcomes in depression: the whole process of care needs to be enhanced. *BMJ Br Med J* 2001;**323**(7319):948.
38. Vanhaecht K, Witte KD, Depreitere R, Sermeus W. Clinical pathway audit tools: a systematic review. *J Nurs Manag* 2006;**14**(7):529–37.
39. Evans-Lacko S, Jarrett M, McCrone P, Thornicroft G. Clinical pathways in psychiatry. *Br J Psychiatry* 2008;**193**(1):4–5.
40. Greenhalgh T, Robert G, Bate P, Kyriakidou O, Macfarlane F, Peacock R. *How to spread good ideas. A systematic review of the literature on diffusion, dissemination and sustainability of innovations in health service delivery and organisation*. 2004.
41. Hawn C. Take two aspirin and tweet me in the morning: how Twitter, Facebook, and other social media are reshaping health care. *Health Aff* 2009;**28**(2):361–8.
42. Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review. *Arch Intern Med* 2003;**163**(12):1409–16.

Please cite this article in press as: Castillo J, et al., Optimizing a magnetic resonance care pathway: A strategy for radiography managers, Radiography (2014), http://dx.doi.org/10.1016/j.radi.2014.09.002

HealthManagement.org
The Journal
LEADERSHIP • CROSS-COLLABORATION • BEST PRACTICE

VOLUME 16 • ISSUE 1 • 2016 • € 22
ISSN = 1377-7629

COVER STORY
Care Continuum

IDEA • BIG DATA • RADIOLOGY • CARDIOLOGY

DOSE MANAGEMENT SPECIAL REPORT

MRI CARE PATHWAY

SUPPORTING A QUALITY MANAGEMENT SYSTEM

Joseph Castillo
Professional Lead
Mater Dei Hospital
Malta
joseph.castillo@gov.mt

Carmel J. Caruana
Associate Professor
Biomedical Physics
Faculty of Health Sciences
University of Malta
Malta

Paul S. Morgan
Honorary Professor
Medical Physics and
Clinical Engineering
Nottingham University
Hospitals
Nottingham, UK

Catherine Westbrook
Senior Lecturer
Faculty of Health, Social
Care and Education
Anglia Ruskin University
Cambridge, UK

Adrian Mizzi
Consultant Radiologist
Medical Imaging Department
Mater Dei Hospital
Malta

In any MRI unit, service quality as experienced by patients depends on the design of the care pathway through which the MRI service is delivered (Johnston and Clark 2005; Yazdanparast et al. 2010). Healthcare organisations can create value in terms of improved service quality by developing expertise, reducing errors, increasing efficiency and improving outcomes (Porter and Teisberg 2004). With an ageing population and rising costs, healthcare organisations have adopted quality management systems (QMS) to improve the effectiveness of treatments and increase patient satisfaction with the service. A QMS is a formal process used to review operations, products and services to identify areas of potential quality improvement. It involves a rigorous, iterative process to continually increase the quality and economic value of services. Creating a quality management system requires a strategic decision, input from employees at all levels of an organisation, and is influenced by varying needs, objectives, the products/services provided, the processes employed and the size and structure of the organisation. The successful implementation of QMS could therefore be hindered through lack of coordination between departments, lack of continuous improvement culture and employees' resistance to change.

A question commonly tackled by radiography managers is: how can a service be managed, controlled, measured, reviewed and improved through the collaboration of all stakeholders (including patients)? One way of contributing to this is through an optimised care pathway design, as the latter is crucial for the attainment of an effective, safe and efficient service (Cheah, 2000).

The European Pathway Association (**e-p-a.org**) defines a care pathway as:

A complex intervention for the mutual decision-making and organisation of predictable care for a well-defined group of patients during a well-defined period.

The key characteristics of pathways include:

- an explicit statement of the goals and key elements of care based on evidence, best practice and patient expectations;
- facilitation of the communication and coordination of roles, and sequencing the activities of the multidisciplinary care team, patients and their relatives;
- documentation, monitoring and evaluation of variances and outcomes; and
- identification of relevant resources.

This project mainly focused on the "facilitation of the communication and coordination of roles, and sequencing the activities of the multidisciplinary care team". Vanhaecht et al. (2010) describe three different coordination models:

- **Chain models:** used for relatively highly predictable care processes with a high level of agreement between the team members;
- **Hub models:** used for less predictable processes with key persons who lead the delivery of the care process;
- **Web models:** used for highly unpredictable, complex processes.

MRI practice involves a mix of routine and non-routine tasks, where employees need to be able to take initiatives in response to incidental findings, or to optimise processes beyond the confines of standard operating procedures (Ponsignon et al. 2011). The MRI care pathway can be considered as a sub-process that fits a chain model, which permits elements of flexibility.

Within this context if care pathways can be optimised to deliver an effective local service they can also be used to support a quality management system.

A literature search did not locate any studies on the optimisation of MRI care pathways to support a QMS. Discussions with international MR radiographers indicated that such development is often carried out using informal methods, which are highly dependent on what is happening elsewhere,

"IF CARE PATHWAYS CAN BE OPTIMISED TO DELIVER EFFECTIVE SERVICES, THEY CAN ALSO BE USED TO SUPPORT A QUALITY MANAGEMENT SYSTEM"

are rarely reported in the public domain and the validities of which are therefore rarely open to scrutiny; in addition, care pathways need to be specific to local healthcare needs and culture.

The purpose of this project was to bring together a multi-stakeholder, interprofessional expert group to develop further and optimise an MRI care pathway model to support an MRI regional quality management system.

Method

Various techniques were considered for the participation of the multi-stakeholder expert group. A literature survey revealed that multi-stakeholder processes that require consensus techniques include the Delphi, nominal group or focus group techniques (Jones and Hunter 1995; Hutchings et al. 2006; Kitzinger 1995). For this study the researchers opted for the nominal group technique (NGT), because the approach allows an adequate number of MRI stakeholders, who could meet in one sitting and voice their opinions freely. To kick-start the process an initial model of the MR care pathway for adults was developed by a small multidisciplinary group comprising an MRI radiographer, radiologist and medical physicist and forwarded to the participants. This ensured that the participants focused on the actual pathway during the NGT process proper. The NGT method used in this study is published elsewhere (Castillo et al. 2015).

Seventeen participants, representing radiologists, radiographers, management, medical physicists, policymakers, physiotherapists and nurses working in orthopaedics, neurosurgery and neurology were invited to create a balanced representation of expertise. Ideally the group of participants should also have included patient representatives, but since these are still very much in their infancy in Malta, nurses working in neurology and orthopaedic wards were invited to participate as patient advocates. This had the added advantage that bias resulting from power inequalities between patients and healthcare professionals was avoided (Vaartio-Rajalin and Leino-Kilpi 2011). Ethical approval was received from the ethics committee of the University of Malta. All participants were provided with information regarding the study, and consent was obtained before the start of the NGT.

Results

Fourteen participants accepted the invitation to participate: an executive from the principal public general hospital, a manager from the national Ministry for Health, a service development manager from the allied healthcare professional sector, 2 senior physiotherapists, 3 nursing officers, 3 MRI radiographers, 2 medical physicists and 1 radiologist. The NGT process resulted in ten issues, which were determined by ranking scores assigned by the participants. These are shown in **Table 1** in decreasing order of importance (the latter quantified using a ranking score).

The group gave a strong affirmative answer when asked if the model as presented by the researchers with the additional 10 issues identified through the NGT was sufficient to form the basis of the desired future MR care pathway. The resulting MR care pathway is shown in **Figure 1**. The pathway shows the patient's journey from when he/she is referred for an MRI scan up to the follow-up visit to the referrer. The numbers in brackets (1- 10) in the diagram refer to the NGT-identified issues from Table 1 relevant to that particular section of the pathway. The pathway is divided into various sub-processes at which defined quality outcomes (indicated with an 'O' in the diagram) and associated criteria would need to be inserted.

The following additional suggestions gleaned from the verbatim transcript of the session, which add further support for the main issues of Table 1 were also incorporated into the care pathway (indicated as (a) – (e) in the diagram):

a. Need for a mechanism to audit the appropriateness of referrals. *"We need to answer the question: has the investigation had an effect on patient management? We are all aware of the high percentage of patients being referred simply because the referrer has no other option - patients insist on an MRI even on occasions when the referrer thinks it is inappropriate."*
b. Need to educate radiographers on procedures to follow for incidental findings: *"Although there is an electronic feedback mechanism linking radiographers and radiologists this is not always being utilised owing to the large throughput."*
c. Importance of the introduction of a radiographers' technical report: *"Radiographers should issue a written technical report in which they confirm that the quality of the images was sufficient for diagnosis, and that safety criteria have been met and to record any variance from the original care plan. This technical report would form the basis for audits…."*
d. The use of social electronic media: *"We should use social electronic media for providing early explanation to patients on what to expect during an MRI scan."*
e. The importance that the referrer qualifies pain levels of patients: *"The referrer should qualify the region and level of pain that the patient may be experiencing. This information would be useful for radiographers to plan the procedure so that the most important sequences are acquired first in relation to the clinical question."*

Table 1. Final ranking of the ten most important care pathway optimisation related issues as determined by the participants

RANK	ITEMS	REMARKS	RANKING SCORE
1	Safety check at referral stage	This will ensure that any contraindications related to metallic implants are resolved at an early stage, hence eliminating delays on the day of the exam proper (Ferris et al. 2007). Psychological issues that may affect the procedure are brought to the attention of the MRI radiography team in advance (Törnqvist et al. 2006; Grey et al. 2000). This will permit specific anxiety reduction protocols to be employed.	80
2	Education of referrers	MRI education for referring clinicians is necessary to avoid inappropriate requests and better use of MR facilities (Blachar et al. 2006; Lehnert and Bree 2010).	78
3	Establish pre-determined objective quality criteria for evaluation and monitoring at critical stages of the care pathway	Clinical criteria are a standard process adopted by all healthcare organisations that espouse the principles of continuous quality improvement (Busch 2010; Barnes et al. 1994; European Society of Radiology 2002).	77
4	Define in terms of effectiveness, safety and efficiency the meaning of 'quality' for each sub-process of the care pathway.	This would ensure that patients receive effective care, in good time and at fair cost (Campbell et al. 2000).	76
5	Early explanation of the procedure to the patient before coming to MRI	An early explanation of the procedure to alleviate anxiety, and identifying in advance those patients with claustrophobia is very important (Bolejko et al. 2008; MacKenzie et al. 1995). Early explanation also improves compliance.	69
6	Establish local referral guidelines (appropriateness criteria)	Referral guidelines to assist the referring clinician in choosing the best imaging modality. This issue is a precursor to issue 2 (Lehnert and Bree 2010; Blackmore et al. 2011; Rosenthal et al. 2006).	66
7	Transparent prioritisation guidelines	Transparent prioritisation guidelines to ensure urgent cases are scheduled earlier and non-urgent cases are prioritised fairly and in a transparent manner. System must be transparent so that clinicians will not hinder its implementation and so that patients feel that they have been respected (Emery et al. 2009).	65
8	Knowledge of the care pathway by all stakeholders	This would ensure that the care pathway is accepted by all stakeholders and that any subsequent modifications are well understood and accepted by the various stakeholders (Evans-Lacko et al. 2010).	55
9	Patient satisfaction surveys	Patient satisfaction surveys are today considered as an indispensable tool to provide client feedback for further improvement of service quality (Nelson and Niederberger 1989; Ware 2003).	50
10	Urgency criteria for diagnostic results following the scan (flagging)	In particular critical incidental findings need to be brought to attention of referring clinicians immediately (Singh et al. 2007; Ferris et al. 2009).	37

Discussion

The MR care pathway describes the tasks performed by the various members of the healthcare team as they interact with each other and the patient. The aim is to achieve the desired defined quality outcomes at various stages of the pathway and carry out regular audit to ensure consistent good quality service. The 10 issues and associated quality criteria should be developed into standard operating procedures and included in the QMS. The "remarks" column in Table 1 provides further explanation and discussion relative to the literature, which would also be included in the standard operating procedures.

It is welcome to note the importance given by the participants to patient safety, education of referrers and the communication of urgent and unexpected findings back to referrer (European Society of Radiology 2012). The group has also identified the importance of involving the referrers at an early stage, insisting that the latter should be knowledgeable about the MRI care pathway, and that they should have access to transparent prioritisation guidelines. This would reduce individual barriers to the implementation of the pathway and the quality management system (Evans-Lacko et al. 2010).

Two other important issues are the importance of referral and quality criteria. The Institute of Medicine Committee on Quality of Health Care in America referred to underuse, overuse and misuse of care as safety threats to patients at both the individual and collective level (Institute of Medicine 2001). Only when compilation, disclosure and evaluation of safety and quality indicators with respect to previously established quality criteria occurs, will the quality of clinical practices be improved (Corrigan 2005). In addition, evaluation should focus not only on end clinical outcomes but also on intermediate sub-processes (Curtis et al. 2006; Von Korff and Goldberg 2001), as proposed in this study. Audit tools in the form of checklists will be developed and used to evaluate key intermediate sub-process outcomes (marked with an 'O' in the diagram) that have major impact on end patient outcomes (Vanhaecht et al. 2006).

The group also raised novel issues. Most importantly for the radiography profession, the group suggested the introduction of a technical report by radiographers that together with the radiologist diagnostic report would provide more complete documentation to the referrer and to management. If integrated within the radiology information system this would certainly facilitate the successful implementation of the pathway (Evans-Lacko et al. 2008; Greenhalgh et al. 2004).

Another novel theme raised by the patient advocates was the importance of referrers indicating the level of pain experienced by patients at the time of the MRI scan request. This would permit radiographers to plan a safer and more comfortable imaging strategy for patients. This important suggestion highlights the capacity of healthcare professionals to act on behalf of patients, and the strength of the NGT method in bringing forth previously unknown issues.

Prior information on the MRI procedure for patients should make better use of interactive information technology. Information about what patients should expect during an MRI procedure would be an effective way of improving the workflow and quality of the service. Although such information is not as widely available as it is desirable, social media

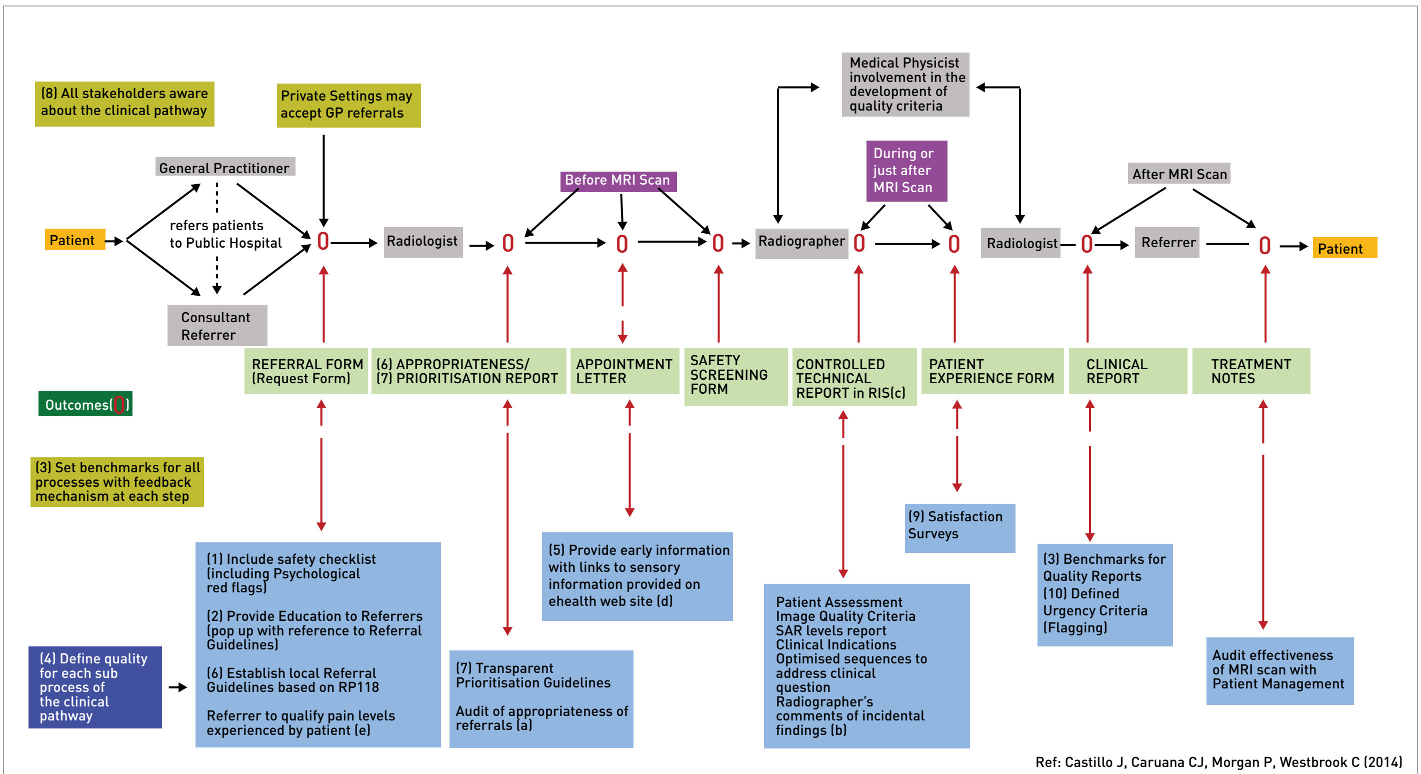


Figure 1. MR Care Pathway

are already being used by patients to liaise with medical practitioners and acquire timely information (Hawn 2009). In addition, web-based clinical decision support systems could assist referring clinicians with respect to referral criteria (Kaushal et al. 2003; Rosenthal et al. 2006).

The production of a prioritised list of issues may be seen as a limitation given that the method involved focusing only on the top 10 issues and setting aside those of lower priority. However, this limitation was addressed by asking all participants to silently generate their own list of issues and thus ensure that all issues have an equal probability of being placed on the discussion agenda. This procedure avoided significant risk of loss of important data when more assertive members of the group dominate, effectively excluding the views of others. One can expect a high level of confidence that the group listed the most important items that should be integrated in the pathway. In addition, the process of selection and prioritisation ensured that the issues that were most important to the participants received the highest level of attention. Without this mechanism, there would have been the risk that the discussion be dominated by one or two contentious issues.

Key Points

- ✓ Optimisation of an MRI care pathway by a multi-stakeholder expert group.
- ✓ Introduction of a radiographer's technical report as an assessment of image quality.
- ✓ Establish quality criteria at each step of the pathway for audit purposes.

Conclusion

This study started from a model of the MR pathway as perceived by a small multidisciplinary group consisting of an MRI radiographer, radiologist and medical physicist, which was in turn subjected to an optimisation process using a nominal group technique. Care pathways are widely believed to be an important tool for ensuring the delivery of high quality, evidence-based care. This paper has presented one example where stakeholders with an interest in MRI and service development came together to contribute to a quality management system. The findings indicate that participants attached the highest importance (rank score >70) to safety, referrer education and defining quality criteria. The NGT method also brought forward novel themes, in particular the need for a radiographer's technical report and the need for referrers to indicate pain levels of patients. The care pathway would provide the necessary data to monitor the service quality. The pathway is considered as a living document and would require periodic ongoing re-evaluation in an iterative process.

Note

The complete study has been published elsewhere (Castillo et al. 2015) dx.doi.org/10.1016/j.radi.2014.09.002

Conflict of interest: None

REFERENCES

Barnes R, Lawton L, Briggs D (1994) Clinical benchmarking improves clinical paths: experience with coronary artery bypass grafting. Jt Comm J Qual Improv, 20(5): 267-76.

Blachar A, Tal S, Mandel A et al. (2006) Preauthorization of CT and MRI examinations: assessment of a managed care preauthorization program based on the ACR appropriateness criteria and the Royal College of Radiology guidelines. J Am Coll Radiol, 3(11): 851-9.

Blackmore CC, Mecklenburg RS, Kaplan GS (2011) Effectiveness of clinical decision support in controlling inappropriate imaging. J Am Coll Radiol, 8(1): 19-25.

Bolejko A, Sarvik C, Hagell P et al. (2008) Meeting patient information needs before magnetic resonance imaging: development and evaluation of an information booklet. Journal of Radiology Nursing, 27(3): 96-102.

Busch HP (2010) [Benchmarking of radiological departments--starting point for successful process optimization] RoFo: Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin, 182(3): 221-8.

Campbell SM, Roland MO, Buetow SA (2000) Defining quality of care. Soc Sci Med, 51(11): 1611-25.

Castillo J, Caruana CJ, Morgan PS et al. (2015) Optimizing a magnetic resonance care pathway: a strategy for radiography managers. Radiography, 21(1): e29-e33.

Cheah J (2000) Development and implementation of a clinical pathway programme in an acute care general hospital in Singapore. Int J Qual Health Care, 12(5): 403-12.

Corrigan JM (2005) Crossing the quality chasm. In: Reid PP, Compton WD, Grossman JH, et al, eds. Building a better delivery system: a new engineering/health care partnership. Washington, DC: National Academies Press.

Curtis JR, Cook DJ, Wall RJ et al. (2006) Intensive care unit quality improvement: a" how-to" guide for the interdisciplinary team. Crit Care Med, 34(1): 211-8.

Emery DJ, Forster AJ, Shojania KG et al. (2009) Management of MRI wait lists in Canada. Healthc Policy, 4(3): 76-86.

European Society of Radiology (ESR) (2012) ESR guidelines for the communication of urgent and unexpected findings. Insights Imaging, 3(1): 1-3.

European Society of Radiology (ESR) (2002) Benchmarking radiological services in Europe. [Accessed: 3 February 2016] Available from myesr.org/html/img/pool/Benchmarking_radiological_services_in_Europe.pdf

Evans-Lacko SE, Jarrett M, McCrone P et al. (2008) Clinical pathways in psychiatry. Br J Psychiatry, 193: 4-5.

Evans-Lacko S, Jarrett M, McCrone P et al. (2010) Facilitators and barriers to implementing clinical care pathways. BMC Health Serv Res, 10: 182.

Ferris NJ, Kavnoudias H, Thiel C et al. (2007) The 2005 Australian MRI safety survey. AJR Am J of Roentgenol, 188(5): 1388-94.

Ferris TG, Johnson SA, Backus M et al. (2009) Electronic results management in pediatric ambulatory care: qualitative assessment. Pediatrics, 123 Suppl 2: S85-91.

Greenhalgh T, Robert G, Bate P et al. (2004) How to spread good ideas. A systematic review of the literature on diffusion, dissemination and sustainability of innovations in health service delivery and organisation. Report for the National Co-ordinating centre for NHS Service Delivery and Organisation R & D (NCCSDO), 1-426.

Grey SJ, Price G, Mathews A (2000) Reduction of anxiety during MR imaging: a controlled trial. Mag Reson Imaging, 18(3): 351-5.

Hawn C (2009) Take two aspirin and tweet me in the morning: how Twitter, Facebook, and other social media are reshaping health care. Health Aff (Millwood), 28(2): 361-8.

Hutchings A, Raine R, Sanderson C et al. (2006) A comparison of formal consensus methods used for developing clinical guidelines. J Health Serv Res Policy, 11(4): 218-24.

Institute of Medicine (2001) Crossing the quality chasm: A new health system for the 21st century, Washington, DC: National Academies Press.

Johnston R, Clark G (2005) Service operations management: improving service delivery. 2nd Edition, Pearson Education: Prentice Hall.

Jones J, Hunter D (1995) Consensus methods for medical and health services research. BMJ, 311(7001): 376-80.

Kaushal R, Shojania KG, Bates DW (2003) Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review. Arch Intern Med, 163(12): 1409-16.

Kitzinger J (1995) Qualitative research. Introducing focus groups. BMJ, 311(7000): 299-302.

Lehnert BE, Bree RL (2010) Analysis of appropriateness of outpatient CT and MRI referred from primary care clinics at an academic medical center: how critical is the need for improved decision support? J Am Coll Radiol, 7(3): 192-7.

MacKenzie R, Sims C, Owens R et al. (1995) Patients' perceptions of magnetic resonance imaging. Clin Radiol, 50(3): 137-43.

Nelson CW, Niederberger J (1989) Patient satisfaction surveys: an opportunity for total quality improvement. Hosp Health Serv Adm, 35(3): 409-27.

Ponsignon F, Smart P, Maull R (2011) Service delivery system design: characteristics and contingencies. International Journal of Operations & Production Management, 31(3): 324-49.

Porter ME, Teisberg EO (2004) Redefining competition in health care. Harv Bus Rev, 82(6): 64-76.

Rosenthal DI, Weilburg JB, Schultz T et al. (2006) Radiology order entry with decision support: initial clinical experience. J Am Coll Radiol, 3(10): 799-806.

Singh H, Arora HS, Vij MS et al. (2007) Communication outcomes of critical imaging results in a computerized notification system. J Am Med Inform Assoc, 14(4): 459-66.

Törnqvist E, Månsson Å, Larsson EM et al. (2006) It's like being in another world–patients' lived experience of magnetic resonance imaging. J Clin Nurs, 15(8): 954-61.

Vaartio-Rajalin H, Leino-Kilpi H (2011) Nurses as patient advocates in oncology care: activities based on literature. Clin J Oncol Nurs, 15(5): 526-32.

Vanhaecht K, Panella M, van Zelm R et al. (2010) An overview on the history and concept of care pathways as complex interventions. International Journal of Care Pathways, 14(10): 117-23.

Vanhaecht K, De Witte KD, Depreitere R et al. (2006) Clinical pathway audit tools: a systematic review. J Nurs Manag, 14(7): 529-37.

Von Korff M, Goldberg D (2001) Improving outcomes in depression. BMJ, 323 (7319): 948-9.

Ware GW (2003) Patient satisfaction surveys. Optometry, 74(10): 671-4.

Yazdanparast A, Manuj I, Swartz SM (2010) Co-creating logistics value: a service-dominant logic perspective. International Journal of Logistics Management, 21(3): 375-403.

Radiography xxx (2016) 1–6

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

An international survey of MRI qualification and certification frameworks with an emphasis on identifying elements of good practice

J. Castillo [a,*], C.J. Caruana [b], P.S. Morgan [c], C. Westbrook [d], A. Mizzi [e]

[a] Mater Dei Hospital and Faculty of Health Sciences, University of Malta, Malta
[b] Medical Physics, Faculty of Health Sciences, University of Malta, Malta
[c] Medical Physics and Clinical Engineering, Nottingham University Hospitals, Nottingham, NG7 2UH, UK
[d] Faculty of Health, Social Care and Education, Anglia Ruskin University, Cambridge, UK
[e] Medical Imaging Department, Mater Dei Hospital, Malta

ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form
12 August 2016
Accepted 24 August 2016
Available online xxx

Keywords:
Magnetic resonance imaging
Education
Certification
Qualification
Competences

ABSTRACT

The purpose of the study was to survey MRI qualification and certification frameworks in the major English-speaking countries (Australia, New Zealand, US, Canada, UK, Ireland) with the aim of identifying elements of good practice. The intention is to incorporate these elements in a national framework that could be used in supporting an MRI specialist register. The study was conducted using document analysis of MRI qualification and certification documents from these states with data triangulated through a web-based questionnaire amongst an expert group of MRI radiographers (n = 59) from the same states. Based on the results of the study, recommendations have been put forward for those countries that are in the process of developing such frameworks. The main recommendations include that a professional or regulatory body externally accredits MRI programmes and that learning outcomes be based on an MRI competence profile that addresses current and forecasted needs of the particular country. The MRI competence profile should encompass a novice-to expert continuum and be referenced directly to a national qualification framework. Ideally each level of expertise should be assessed and evidenced by a portfolio of CPD activities, including clinical and management case studies appropriate to that level.

Introduction

As magnetic resonance imaging (MRI) hardware, techniques and clinical applications expand there is a greater need for radiographers with a high level of expertise particularly at larger medical centers offering a wide spectrum of both routine and complex clinical studies and a possible element of research. This expertise should be recognised through a formal national qualification and certification process[1,2] based on a competence profile[3] which reflects the present and forecasted future national service portfolio and MRI care pathway.[4,5] Undergraduate radiography programmes often include an MRI component but this is mostly limited to safety screening and patient positioning for common routine procedures.[6] Following qualification, entry level radiographers perform, under supervision, routine non-complex procedures that do not require advanced protocol modification with respect to individual patient or pathology. Further training may be acquired through hands-on practice provided in-house and continuing professional development. Concern has been expressed that such activities are rarely assessed formally and may be insufficient to confer sufficient expertise.[7–9] In 2012, the European Federation of Radiographer Societies published a position paper (in response to Electromagnetic Fields Directive 2004/40/EC)[10] stating that it aims to develop requirements for MRI qualification and certification. However, to date no such European framework has been published. In such absence of a European framework the major English-speaking countries were surveyed with the purpose of identifying elements of good practice to guide the setting up of a national qualification and certification framework. Owing to the variability in meaning in the literature critical terms used in the study are defined in Table 1 below.

* Corresponding author.
E-mail addresses: joseph.castillo@gov.mt (J. Castillo), carmel.j.caruana@um.edu.mt (C.J. Caruana), paul.morgan@nottingham.ac.uk (P.S. Morgan), Catherine.westbrook@anglia.ac.uk (C. Westbrook), Adrian.Mizzi@gov.mt (A. Mizzi).

http://dx.doi.org/10.1016/j.radi.2016.08.009
1078-8174/

Table 1
Definitions used in this study.

Qualification	An award by a competent body that formally recognises that an individual has achieved learning outcomes to a given standard.[11,12] A qualification can be academic (often awarded by a competent institution of higher education) or professional (normally awarded by a competent professional body or public body).
Certification	A formal process that leads to a recognition that an individual possesses the necessary academic and professional qualifications to be fit for practice at a specific level of expertise.[13,14]
Registration	A requirement for an individual to apply for and gain inclusion of one's name on a list of persons with a legal right to exercise a given profession following certification.[14]
Competence	the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development described in terms of *responsibility and autonomy*.[11,12]
Competence profile	An inventory of competences attached to a class of healthcare professionals, in this case, the MRI radiographer, at a specific level of expertise.[12]
Programme accreditation	A quality assurance process through which an education or training activity is officially evaluated against predetermined standards and approved by relevant legislative or professional authorities *external to the provider*.[12]

Materials and methods

The study was conducted using a documentary analysis[15] of MRI qualification and certification documents from the major English speaking countries (Australia, New Zealand, US, Canada, UK, Ireland). These countries were chosen as educational provision and/or role development is relatively advanced and related documentation often well-developed and easily available.[16] Documentary analysis is a research strategy often used in educational research.[17–19] Advantages of documentary analysis are that documents provide records of present frameworks and future proposals. Documents are often available in the public domain and ethical issues are rarely problematic. Documents were retrieved from official websites of regulatory authorities, national and international professional societies, universities and accreditation institutions. The main limitations of documentary analysis are that documents may sometimes not be sufficiently current[20] and that the researcher may extract data that best supports his/her own interpretation of the data.[15,21] To reduce the effect of the former limitation, websites were regularly rechecked for updates and findings were double checked by triangulation with information solicited through a web-based questionnaire amongst a select group of MRI expert radiographers (n = 59) from the countries involved. The experts chosen were members of the ISMRM who were involved in MRI education and/or MRI advanced practice in their respective countries. When the level of agreement between the two sources of data was considered insufficient the issue was clarified further via direct email communication. The questionnaire included 18 close-ended and 16 open-ended questions on MRI qualifications, certification, competence profiles, registration and role of regulatory organisations. The questions were structured to strictly reflect the research objectives and validated by a group of subject matter experts which included a MR radiographer, consultant radiologist and a medical physicist who had both clinical and pedagogical experience. Piloting of the questionnaire was carried out with a small international group of MR radiographers since it was intended for international participation. The questionnaire can be obtained from the first author or viewed at https://www.surveymonkey.com/r/XKV8PV7. All responses were anonymised by setting the software to hide IP addresses. To reduce the effect of researcher bias a second independent researcher was requested to re-analyse the documentary and questionnaire data. The final interpretation was sent to a second group of independent MRI experts (n = 6) from the countries involved for validation. Approval to carry out the study was obtained from the University of Malta Research Ethics Committee (proposal no 104/2013).

The data analysis focused on the following categories: MRI qualifications (including programme accreditation), certification, registration and competence profiles. Key sentences/phrases or statements which were identified as descriptors related to each of the above categories were highlighted in the text. Relevant data were subsequently inserted into the corresponding categories and checked for levels of hierarchy, interconnections and repetition. A summary of the data can be found in Table 2. Table 3 gives details of the types of institutions offering MRI programmes and details of accreditation. The decision whether a particular practice constitutes good practice or otherwise was based on whether the particular practice is consonant with the spirit of the quality oriented recommendations of the EQF (particularly Annex III which deals specifically with quality.[22]

Findings

Qualifications

PGDip and Masters programme accreditation varies from one country to another and may be provided by a national professional society, health ministry, university, or national accreditation agency. University or college based MRI programmes in Canada, New Zealand, Australia and the US are externally accredited by national accreditation bodies whilst in the case of the UK and Ireland external accreditation is provided by professional societies.

The pre-requisite qualification to enter PGDip or Masters education programmes in MRI is generally a university undergraduate degree or a higher undergraduate diploma in radiography. Clinical entry requirements vary widely with some institutions asking for post-registration MRI experience, whilst others (e.g., New Zealand, Ireland) do not and include a clinical component in the programme proper. In all countries, teaching, supervision and assessment is shared between university tutors, clinical instructors and qualified MRI radiographers. The assessment includes a variable assortment of portfolios of evidence, assignments, examinations and dissertation.

Certification, registration and competence profiles

Due to the diversity in certification frameworks, registration, and competence the findings will be presented country by country.

Australia

To practice radiography in Australia one must graduate from an accredited university programme in general radiography and then enrol in 48 weeks of clinical supervised practice. Although undergraduate programmes cover basic MRI physics, only limited clinical MRI training is provided.[24] The Australian Institute of Radiography (AIR) therefore recommends that MRI practitioners undergo specific training and supervised clinical experience. AIR

Table 2
Key findings from the analysis of documents and triangulation questionnaire.

Country	Qualification	Certification	Registration	MRI competence profile	Notes
Australia	PGDip and Masters courses in MRI available.	No formal certification specific to MRI.	Entry-level radiographers registered by the Medical Radiation Practice Board (MRPB) following a degree in radiography. The Australian Institute of Radiography (AIR) maintains a non-compulsory register for MRI radiographers. Two registration levels available: Level 1 is based on a written test; Level 2 requires clinical experience and CPD portfolio. PGDip or MSc not mandatory for registration.	No national MRI competence profile exists.	AIR has published generic professional standards referenced to the Australian Qualification Framework. MRPB issued a separate inventory of 'capability statements' very similar to AIR but not specific to MRI.
New Zealand	PGDip in MRI available.	Requirements for MRI certification are a BSc in Medical Imaging and PGDip in MRI combined with MRI experience. However, those who do not have a PGDip in MRI can submit any MRI qualification or any qualification and experience in another appropriate imaging modality but must sit and pass a specific board registration examination assessment (REA) in MRI. If MRI qualification does not include a clinical component one has to complete 3360 h of clinical MRI practice before the REA.	MRI technologists are registered by the Medical Radiation Technologists Board (MRTB). Two levels of MRI registration are available -Trainee and Full. Registration is compulsory and so is annual re-registration.	National MRI competence profile exists and includes three levels of expertise. The competence profile is widely used as a curriculum blueprint by tertiary educational institutions.	Ongoing debate whether qualification and certification framework should be changed — effectively to lower the requirements to allow more radiographers to practise MRI.
US	Accredited MRI specific undergraduate academic programs available.	Certification based on certification examination run by state, ARRT or ARMRIT. Additional certification may be required for specific MRI applications e.g., cardiac MRI.	There are two pathways to acquire registration: 'Post-primary' available only to 'radiologic technologists', and 'primary' open to non-radiological technologists. Once MRI registered registration must be maintained through a CPD portfolio.	National MRI competence profile developed by the American Society of Radiologic Technologists (ASRT)	Detailed MRI syllabus developed by ASRT, SMRT and AEIRS.
Canada	MRI Diploma programmes at institutes of technology or college available.	Radiation technologists are expected to have completed an accredited MRI programme from an institute of technology or college and enrol in MRI CPD programs to obtain and maintain certification. CAMRT recognises two levels of MRI certification. 'Discipline 1' (only in Alberta) and 'Discipline 2' open to students who have completed a medical imaging course.	Registration with CAMRT is based on a national certification examination which is based on a national competence profile. MR Technologists expected to enrol in CPD.	CAMRT provides a national MRI specific competence profile for entry level practices but not for advanced practice.	Although no MRI competence profile developed for experienced technologists, CAMRT has introduced 'Best Practice Guidelines'.
UK	Several MRI MSc and PGDip available.	No formal certification specific to MRI available.	Radiographers are registered by the Health and Care Professions Council. There is no separate registration for MRI radiographers and post-graduate qualification or certification in MRI is not mandatory for employment. Selected radiographers are asked to submit a CPD portfolio.	Skills for Health had developed a competence profile for MRI.	A generic education and career framework developed by the SOR serves as a guideline for professional development at various levels of expertise, however none MRI specific.
Ireland	MRI MSc and PGDip available.	No formal certification specific to MRI available.	Entry radiographers are registered by the radiography registration board, but no separate registration for MRI radiographers. No MRI qualification or certification is mandated but qualification is highly desirable and a requirement for the post of 'MRI clinical specialist'. Selected radiographers asked to submit a portfolio of evidence showing they have attained 60 CPD credits over 24 months.	No detailed MRI specific competence profile exist.	'Guidelines on Best Practice in MRI' have been published by the Irish Institute of Radiography and Radiation Therapy (IIRRT) and includes responsibilities expected from the MRI clinical specialist and the MRI radiographer.

Table 3
Types of institutions offering MRI programmes and methods of programme accreditation.

Country	Institutions offering MRI programmes	Accreditation body
Australia	Only University of Queensland offers MRI specific Masters programme. Charles Sturt University and University of Sydney offer Masters programmes in medical imaging sciences (with PGDip in MRI – exit point only).	Medical Radiation Practice Accreditation Committee within the Medical Radiation Practice Board of Australia (MRPB)
New Zealand	Only University of Auckland offers an MRI programme (PGDip).	Regulatory Authority for Medical Radiation Technologists under the auspices of the Ministry of Health
US	Universities and colleges	Joint review commission on education in radiologic technology (JRCERT) or by other accreditors that are in turn accredited by the Council for Higher Education Accreditation (CHEA) or the US Department of Education (USDE).
Canada	Institutes of technology and colleges offers 'Discipline 1' and 'Discipline 2' diploma programmes.	Consortium of national and provincial organizations, colleges and universities ensures requirements set by the Canadian Association of Medical Radiological Technologists (CAMRT) and Canadian Medical Association.
UK	Several PGDip and Masters in MRI offered.	College of Radiographers, Approval and Accreditation Board.[23]
Ireland	University College Dublin (UCD) and Trinity College Dublin offer postgraduate education (both PGDip and MSc) in MRI.	Only the UCD programme is accredited by IIRRT.

accredits two levels of post-qualification MRI certification: level 1 (basic) and level 2 (advanced).[24,25] Although AIR maintains a register of radiographers certified at both levels, this is voluntary, and in practice no qualification or certification is required to practice (Table 2). Public hospitals often require AIR certification whereas private clinics do not.[26] In the absence of a national MRI-specific competence profile, some hospitals have developed their own. In 2014, AIR launched an advanced practitioner pathway that is referenced to the Australian Qualification Framework and which incorporates the professional practice standards revised in 2013.[27,28] However, the listed competences are generic and not modality specific. The MRPB also issued an inventory of knowledge, skills and 'attributes' necessary for practice but at entry level.[29]

New Zealand

The "scope of practice and related qualifications" of the Medical Radiation Technologists Board (MRTB) of New Zealand states that in order to be certified and registered to work in MRI, radiographers must have a first degree in radiography/medical imaging and a PGDip in MRI from a New Zealand tertiary education provider that is accredited and monitored by the MRTB.[30] However, there is an alternative pathway for registration – the REA (see Table 2),[30] The listing in the MRI register is compulsory and all radiographers must take part in CPD. The competence profile is also used to provide guidelines for tertiary institutions that are providing MRI programmes, to assist in the development of curricula and to monitor programme delivery. It includes three skill levels[31] but these levels are not referenced to a national qualification framework. Skill level 1 ("can perform some parts of the skill satisfactorily but requires guidance and/or supervision to perform the entire skill") is not referenced to any competence profile; level 2 ("can perform the skill satisfactorily but requires guidance and/or supervision") requires only the acquisition of a small subset of competences; level 3 ("can perform the skill satisfactorily without guidance and/or supervision") requires the acquisition of the great majority of competences. Annual re-certification is required and 10% of radiographers are asked to submit a CPD portfolio as part of the Board's audit process.

United States

Radiologic and MRI 'technologists' must be registered in some states, but requirements vary by state. To become registered, technologists must graduate from an accredited academic program and must pass a certification exam from the state or from the American Registry of Radiologic Technologists (ARRT). To be certified in MRI, two pathways are available (see Table 2). MRI certification can be obtained by sitting an examination organised either by the ARRT or the American Registry of MRI Technologists (ARMRIT), after successfully following an accredited academic programme in MRI. The content of both the ARMRIT and ARRT certification examinations are based on a job analysis study involving a large sample of MRI technologists[32,33] and a formal MRI curriculum development process by the American Society of Radiologic Technologists (ASRT), the Section of Magnetic Resonance Technologists (ISMRM-SMRT), and the Association of Educators in Imaging and Radiologic Sciences (AEIRS).[34] The ARRT certification is based on academic and professional qualifications[35]; following certification annual registration is maintained by submitting a CPD portfolio based on 24 credits accrued over 2 years. Additional certification by a supervising physician may be required for specific applications such as cardiac MRI.[36] From January 1, 2015, all primary pathway candidates for certification in MRI were required to earn an academic degree for certification (Table 2).[37]

Canada

In January 2014, the Canadian Association of Medical Radiologic Technologists (CAMRT) published a new MRI competence profile to be implemented in the May 2018 certification exams for entry level MRI technologists, but not for more experienced practitioners.[38] This profile is typically reviewed every five years and serves as a blueprint for curriculum development. MRI certification is mandatory and awarded by CAMRT based on a national certification exam after the candidate completes an accredited educational program in MRI. CAMRT recognises two levels of MRI diploma programmes and students are eligible to work as MRI technologists anywhere in Canada if they pass the CAMRT national exam. In the provinces of Ontario, Nova Scotia and Alberta, one must also belong to the provincial regulatory college.[39–41] Although CPD is not mandatory for re-certification, it is expected. CAMRT has introduced 'Best Practice Guidelines' to assist experienced practitioner during decision making for specific clinical circumstances including safety (see summary in Table 2).[42]

United Kingdom

In the UK, Skills for Health, which is an independent council within the National Health Service and representing a range of healthcare employers, developed a national MRI competence profile ('occupational standards') which cover key MRI activities.[43,44]

These standards are not mandatory and not expressed in the knowledge, skills, and competences format required by the European Qualification Framework (EQF)[22] nor developed along a novice-to-expert continuum.[45,46] Although the Society of Radiographers has published an education and career framework to serve as a guideline for generic professional development (and which includes outcomes for the various levels of expertise),[47] the document falls short of defining the required specific knowledge, skills, and competences and does not reference the EQF. The UK has mandatory registration for all radiographers qualified in general radiography via the Health and Care Professions Council (HCPC) with a mandatory biennial re-registration based on the presentation of a portfolio of CPD activities within the radiographer's scope of practice. This means that a selection of radiographers working in MRI would need to present evidence of their experience in MRI (see Table 2).[48]

Ireland

To practice radiography in Ireland one must graduate from an accredited university and register with the radiographers' registration board of the Health & Social Care Professionals Council (CORU).[49] The Irish Institute of Radiography and Radiation Therapy (IIRRT) has published a ‘Guidelines on Best Practice’ document[50] which recommends that to work in MRI a radiographer should either undertake a course of postgraduate education in MRI approved by the IIRRT or be considered by the Radiography Service Manager in consultation with the MRI clinical specialist radiographer (CSR). The latter must have at least 6 years' experience in MRI and possess a postgraduate qualification in MRI at EQF level 7.[50] The CSR is responsible for day-to-day responsibility of the MRI department including quality assurance, procurement and development of imaging protocols. In the absence of the supervising consultant radiologist the MRI CSR is deemed the responsible person for all patient/staff safety issues.

The ‘Guidelines on Best Practice’ describes a comprehensive list of professional responsibilities that are required by the MRI radiographer to mainly ensure safety of the patient and staff within the MRI environment[50] however there is no reference to the EQF.[22] Ireland has mandatory re-registration for all radiographers which includes the presentation of a portfolio covering 60 CPD activities within a 24-month cycle and within the radiographer's actual scope of practice which could be MRI (see Table 2).[51]

Discussion

The study highlights similarities and differences in the qualification and certification frameworks of MRI radiographers in the major English speaking countries. Canada and New Zealand have mandatory certification and registration based on national MRI-specific competence profiles and a higher education qualification obtained from an accredited centre. A similar trend has been followed in the US since January 2015. In Australia, the AIR offers a certification and registration pathway referenced to a national qualification framework[27] and to a set of generic professional practices standards. However, these standards are not mandatory for employment. The UK and Ireland do not offer MRI specific certification and registration, but radiographers are required to maintain a CPD portfolio that reflects their actual scope of practice which could be MRI. The lack of mandatory assessment in the UK has raised concerns regarding safety.[7] In Ireland, a postgraduate qualification and number of years of experience is mandatory for the post of ‘MRI clinical specialist’. The provision of mandatory postgraduate qualification in MRI, from an accredited higher education institution (as opposed to informal non-formally assessed training), together with a specified number of years of supervised experience in MRI as pre-requisites to certification would be considered elements of good practice. If such postgraduate qualifications have a well-defined scope they would facilitate comparability and hence may contribute to improved mobility across national, regional, and international boundaries.[12] Programmes based on a national competence profile that is in turn developed on an analysis of practice,[32] present and future national service portfolios and care pathways[4,5] is another important element of good practice. Competence profiles can also be used by MR department managers to support the development of their staff. For the individual MRI professional the profile can be used as a self-assessment tool to gauge own level of professional development. Canada and the US each have an MRI competence profile, but unlike others developed by other professions such as nursing,[52] these are not framed within a novice-to-expert continuum as suggested by Dreyfus,[45,53] Benner[46] and Yielder.[54] Having said this, the MRI-specific competence profile in New Zealand is referenced to three distinctive ‘skill levels’. However, a competence profile based on a theoretical conceptual framework such as that of Dreyfus, Benner and Yielder would be good practice. The utilization of a clinical portfolio as in New Zealand, the UK, Ireland and Australia would ensure that certification be based on evidence.[55] Another element of good practice is to ensure that the competence profile is referenced to a national qualification framework. The findings indicate that this was only proposed by the AIR (Australia) and surprisingly was not adopted by the Australian regulatory board. In the case of Europe, mobility may be enhanced if national qualification and certification frameworks are based on competence profiles and referenced to the EQF. Certification would ideally be carried out by a nationally accredited professional or regulatory body and would provide a statement of fitness to practice at a particular level of expertise. A separate MRI register maintained by a regulatory body as in the US, Canada, and New Zealand is another element of good practice.

Conclusion and recommendations

This paper has analysed MRI qualification and certification frameworks including associated registration requirements and competence profiles in the major English speaking countries and identified elements of good practice. Some countries have well established frameworks whilst in others such frameworks are being developed and are a work in progress. Continuous update of competence profiles is crucial, since service portfolios change with time in response to the ever-changing needs of the healthcare system. It is proposed that a professional or regulatory body accredit MRI post-graduate academic and clinical programmes and that learning outcomes be based on an MRI competence profile that addresses the current and forecasted future needs of the particular country. The MRI competence profile should be structured in a novice-to-expert continuum format and should be referenced directly to a national qualification and certification framework. Ideally each level of expertise should be formally assessed and the clinical component evidenced by a portfolio of CPD activities which should include clinical and managerial case studies appropriate to that particular level. MRI certification should be mandatory, managed by a professional or regulatory body and lead to formal registration in an MRI specialist register.

Conflict of interest statement

None.

Acknowledgements

Ms Maria Boyd (CA), Ms Diana Pilkington (AU), Ms Wendy Stirnkob (US), Ms Rachel Watt (UK), Ms Shelley Park (NZ), Mr Ben Kennedy (AU).

References

1. Pierce E, Belling R. Advanced practitioner roles: relevance and sustainability in a 'liberated'NHS. *Health* 2010:5.
2. White P. The specialist radiographer–does the role justify the title? *Radiography* 2004;**10**(3):217.
3. European Commission. *European reference competence profile for PES and EURES counsellors*. 2014. Brussels.
4. Castillo J, Caruana CJ, Morgan PS, Westbrook C. Radiographer managers and service development: a Delphi study to determine an MRI service portfolio for year 2020. *Radiography* 2015;**21**(1):e21–7.
5. Castillo J, Caruana CJ, Morgan PS, Westbrook C. Optimizing a magnetic resonance care pathway: a strategy for radiography managers. *Radiography* 2015;**21**(1):e29–33.
6. Portanier Mifsud C, Castillo J, Portelli JL. Radiography students' clinical placement experiences in MRI: a phenomenological study. *Radiography* 2014;**21**(1):e17–20.
7. Westbrook C, Talbot J. What do MRI radiographers really know? *Eur J Radiogr* 2009;**1**(2):52–60.
8. Ribeiro A, Nunes A and Gois C. Characterization of the radiological technician's knowledge about safe MR practices, [unpublished work], 3rd Euro-Med Congress Radiographers, Lispbon, Portugal 2010.
9. Moberg K. *Magneettikuvantamisessa Tyoskentelevien Rontgenhoita-Jien Koulutuksen Kehittaminen Heidan Nakokulmastaan (MRI radiographers Educations Development in view of radiographers)*. Finland: Faculty of Medicine, Institute of Health Sciences, Radiography, University of Oulu; 2013.
10. European Federation of Radiographer Societies. *Position paper on directive 2004/40/EC the electromagnetic fields directive*. 2012. http://www.ft.dk/samling/20111/almdel/beu/bilag/83/1071456.pdf [accessed 19.09.14].
11. European Parliament and Council. Recommendation 2008/C 111/01 on the establishment of the European Qualifications Framework for lifelong learning, Official J Eur Union, 6.5.2008.
12. The European Centre for the Development of Vocational Training. In: J Calleja James, editor. *Terminology of European education and training*. 2nd ed. Luxembourg: Publications office of the European Union; 2014.
13. Rooney AL, van Ostenberg PR. Licensure, accreditation, and certification: approaches to health services quality. *Qual Assur Methodol Refinement Ser* 1999. Bethesda: Quality Assurance Project.
14. Human Resources Professionals Association. *HRPA glossary of professional regulation and certification terms*. 2010. http://www.hrpa.ca/RegulationandHRDesignations/Documents/Glossaryregulationcertificationprofessionalstandards.pdf [accessed 5.05.15].
15. Shaw S, Elston J, Abbott S. Comparative analysis of health policy implementation. *Policy Stud* 2004;**25**(4):259–66.
16. Cowling C. A global overview of the changing roles of radiographers. *Radiography* 2008;**14**(Suppl. 1):28–32.
17. Momeni P, Jirwe M, Emami A. Enabling nursing students to become culturally competent–a documentary analysis of curricula in all Swedish nursing programs. *Scand J Caring Sci* 2008;**22**(4):499–506.
18. Fitzgerald T. Documents and documentary analysis: reading between the lines. *Res Methods Educ Leadersh Manag* 2007;**2**:278–94.
19. Blundell EG. *Document analysis as a qualitative research technique in assessing oral health policy*. Dalhousie University; 2012.
20. Caruana CJ, Plasek J. A SWOT audit for the educator role of the biomedical physics academic within Faculties of Health Science in Europe. *Proc GIREP* 2006:899–903.
21. Appleton JV, Cowley S. Analysing clinical practice guidelines. A method of documentary analysis. *J Adv Nurs* 1997;**25**(5):1008–17.
22. European Commission. *The European qualification framework for lifelong learning (EQF)*. 2008. http://www.ond.vlaanderen.be/hogeronderwijs/bologna/news/EQF_EN.pdf.
23. The Society of Radiographers. *Approval and accreditation board*. 2016. http://sor.org/learning/education-accreditation/approval-and-accreditation-board [accessed 10.08.16].
24. Australian Institute of Radiography Education Policies. http://www.air.asn.au/cms_files/10_Publications/policies_guidelines/education_policies_dec2010.pdf; 2010.
25. Australian Institute of Radiography. *MIAP1 policies and procedures*. 2014. p. 16. Available at: http://www.air.asn.au/cms_files/05_Accreditation/mri/mri_policies_procedures_final_dec14.pdf.
26. Strugnell W. MRI education and certification forum: Australia and New Zealand. In: *15th SMRT Annual Meeting, Seattle Washington USA*; 2006.
27. Advanced Practice Advisory Panel. *Pathway to advanced practice*. 2014. http://www.air.asn.au./advanced.php.
28. Australian Institute of Radiography. *Professional practice standards for the accredited practitioner*. 2013. http://www.air.asn.au/cms_files/10_Publications/policies_guidelines/pps_air_dec2013.pdf.
29. Medical Radiation Practice Board of Australia. *Professional capabilities for medical radiation practice*. 2013 [professional standards], http://www.medicalradiationpracticeboard.gov.au/documents/default.aspx?record=WD13%2f12534&dbid=AP&chksum=OIuB81d6eQCqo%2bewP9PHOA%3d%3d.
30. New Zealand Medical Radiation Technologists Board. *Notice replacing prescribed scope of practice and related qualifications*. 2013. http://www.mrtboard.org.nz/assets_mrtb/Uploads/MRT-SOP-and-Quals-notice-31.07.3.pdf.
31. New Zealand Medical Radiation Technologists Board. *Competencies required for the practice of: Magnetic resonance imaging*. 2011. http://www.mrtboard.org.nz/assets_mrtb/Uploads/MRI-Competencies-Approved-March-7.pdf.
32. The American Registry of Radiologic Technologists. *Practice analysis*. 2015. https://www.arrt.org/practice-analysis/ [accessed 1.05.15].
33. American Registry of MRI Technologists. *Job analysis survey*. 2015. http://www.armrit.org/pdf/ECSurveyTextWeb.pdf.
34. ASRT, SMRT, AEIRS. *Magnetic resonance curriculum*. 2008. http://www.ismrm.org/smrt/mr_curriculum08.pdf.
35. The American Registry of Radiologic Technologists. *Primary certification didactic and clinical competency requirements in Magnetic Resonance Imaging*. 2014. https://www.arrt.org/pdfs/Disciplines/Competency-Requirements/MRI-Competency-Requirements.pdf.
36. American College of Radiology. *ACR Practice guideline for the performance and interpretation of cardiac magnetic resonance imaging (MRI)*. 2006. http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/MRI_Cardiac.pdf.
37. The American Registry of Radiologic Technologists. *Initial ARRT certification and registration*. 2015. https://www.arrt.org/Certification [accessed June, 2016].
38. Canadian Association of Medical Radiation Technologists. *Magnetic resonance competency profile*. 2014. http://www.camrt.ca/wp-content/uploads/2015/03/MR-profile-Final.pdf.
39. Nova Scotia Association of Medical Radiation Technologists. *College information*. 2015. http://nsamrt.ca/act/index2.html [accessed 16.03.15].
40. College of Medical Radiation Technologists of Ontario. *Registration*. 2015. https://www.cmrto.org/what-we-do/registration/.
41. Alberta College of Medical Diagnistic and Therapeutic Technologists. *Registration*. 2015. http://acmdtt.com/registration/general-registration/ [accessed 16.03.15].
42. Canadian Association of Medical Radiation Technologists. *Best practice guidelines*. 2015. https://ww2.camrt.ca/bpg/ [accessed November, 2015].
43. Skills for Health. *Strategic plan 2010–15*. 2009. http://www.skillsforhealth.org.uk/~/media/Resource-Library/PDF/Strategic%20Plan%202010-15%20Mar%202010.ashx [accessed 7.02.11].
44. Skills for Health. *CHS107 acquire magnetic resonance images for diagnostic purposes*. 2007. p. 1–7. Available at: https://tools.skillsforhealth.org.uk/competence/show?code=CHS107.
45. Dreyfus SE. The five-stage model of adult skill acquisition. *Bull Sci Technol Soc* 2004;**24**(3):177–81.
46. Benner P. From novice to expert. *AJN Am J Nurs* 1982;**82**(3):402–7.
47. The Society of Radiographers. *Education and career framework for the radiography workforce*. 2013. http://www.sor.org/learning/document-library/education-and-career-framework-radiography-workforce [accessed 17.03.15].
48. Health and Care Professional Council. *Your guide to our standards for continuing professional development*. 2011. http://www.hcpc-uk.org/assets/documents/10003B70Yourguidetoourstandardsofcontinuingprofessionaldevelopment.pdf [accessed 5.05.15].
49. Radiographers Registration Board. Criteria and standards of proficiency education and training programmes.
50. Irish Institute of Radiography and Radiation Therapy. *Magnetic resonance imaging. guidelines on best practice*. 2014.
51. Health and Social Care Professionals Council. *CPD requirements*. 2016. http://coru.ie/uploads/documents/Final_CPD_framework_document.pdf [accessed June, 2016].
52. Royal College of Nurses. *Integrated core career and competence framework for registered nurses*. 2009. https://www.rcn.org.uk/__data/assets/pdf_file/0005/276449/003053.pdf [accessed 7.05.15].
53. Dreyfus SE, Dreyfus HL. *A five-stage model of the mental activities involved in directed skill acquisition*. 1980. DTIC Document.
54. Yielder J. An integrated model of professional expertise and its implications for higher education. *Int J Lifelong Educ* 2004;**23**(1):60–80.
55. McMullan M, Endacott R, Gray MA, Jasper M, Miller CML, Scholes J, et al. Portfolios and assessment of competence: a review of the literature. *J Adv Nurs* 2003;**41**(3):283–94.

European Congress of Radiology 2017

VALIDATION OF A COMPETENCE PROFILE FOR MAGNETIC RESONANCE RADIOGRAPHERS USING A FORMAL RESEARCH PROCESS

J. Castillo[1], C. J. Caruana[1], P. S. Morgan[2], C. Westbrook[3], A. Mizzi[4]

[1] University of Malta, Msida, Malta
[2] Nottingham University Hospitals, Nottingham, UK
[3] Anglia Ruskin University, Cambridge, UK
[4] Mater Dei Hospital, Msida, Malta

INTRODUCTION

- Studies in MR education indicate insufficient education of MR practitioners.
- In the European Qualifications Framework (EQF) competence is defined in terms of 'responsibility and autonomy'.
- A competence profile (CP) is a list of key responsibilities for a given class of health care professionals.

BENEFITS OF COMPETENCE PROFILE (CP)

- CPs can help students form accurate perceptions of a professional discipline.
- Faculty can use CPs to design curricular content.
- Employers can use CPs to communicate their expectations to educators and to guide professional development for employees.
- For the individual healthcare professional CPs can be used to assess own level of professional development.
- CPs provide a tool for international comparability and facilitate mobility of professionals across borders.

PURPOSE OF THE STUDY

- To develop and validate a context specific competence profile for MR radiographers that would be necessary and sufficient to deliver a forecasted MR service portfolio and care pathway in Malta
- The competence profile should be structured and range from entry to expert level.

METHODOLOGY

- The development of the competence profile was preceded by three subsidiary studies the results of which fed into the development of the profile:
  - 1. A forecasted national MR service portfolio for year 2020 was developed[1],
  - 2. The national MR care pathway was optimized[2] ,
  - 3. A qualitative documentary survey of MR qualification and certification frameworks in the major English speaking countries was carried out to identify any elements of best practice[3].

1. Castillo J, Caruana CJ, Morgan PS, et al. Radiographer managers and service development: A Delphi study to determine an MRI service portfolio for year 2020. Radiography 2015;**21**(1):e21-e27.
2. Castillo J, Caruana CJ, Morgan PS, et al. Optimizing a magnetic resonance care pathway: A strategy for radiography managers. Radiography 2015;**21**(1):e29-e33.
3. Submitted for review.

METHODOLOGY (CONT.)

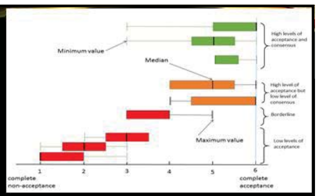
- An initial blueprint of the MR competence profile was reviewed by a group of subject matter experts.
- The list of MR competences with an attached 6-level Likert scale was piloted by two additional radiographers who are in possession of a higher qualification in MR imaging at EQF level 7.
- The Delphi technique was then used to validate the blueprint by a multi-stakeholder MR expert group.

METHODOLOGY (CONT.)

- The competence profile included 43 competences grouped under 7 key activities
  - Image Acquisition (IA) - 20 competences
  - Education (E)- 6 competences
  - Quality Assurance (QA) - 5 competences
  - Safety and Risk Management (SRM) - 2 competences
  - Service Unit Management (SUM) - 4 competences
  - Facility Management (FM) - 5 competences
  - Research (RES) - 1 competence

The full profile can be viewed on EPOS B-0149 (control no 6863)

METHODOLOGY



Level of ACCEPTANCE (level agreement WITH A GIVEN COMPETENCE STATEMENT)

Assessed as the median value on a 6 point Likert scale ranging from 1 (complete non-acceptance) to 6 (complete acceptance).

Target level of acceptance: Median ≥ 5

Level of CONSENSUS (level of agreement AMONG THE PARTICIPANTS)

Assessed using the interquartile range (IQR)

Target level of consensus: IQR ≤ 1

RESULTS: 1ST ROUND

- 37 of the statements achieved the target level of acceptance and consensus (median ≥ 5, IQR ≤ 1.0)
- 5 statements (IA16, IA19, IA20, E3, FM3) obtained high acceptance but low consensus (median ≥ 5, IQR ≥ 1.0)
- 1 statement (IA3) obtained low acceptance and high consensus (median = 4.0, IQR of 1.0)
- 6 other statements (IA1,IA9,IA10, QA4,QA5,SRM2) required rewording based on the qualitative analysis of the respondents' comments.

RESULTS: 2ND ROUND

- 7 of the statements (IA1, IA3, IA9, IA10, IA19, QA5 and FM3) achieved the target level of acceptance and consensus (median ≥ 5, IQR ≤ 1.0)
- 3 statements (IA16, IA20 and E3) retained a high level of acceptance but low level of consensus (median ≥ 5, IQR = 1.5 respectively). This was attributed to a difference of opinion between radiography and radiology participants.
- 2 statements (QA4 and SRM2) retained a high level of acceptance but showed a lower level of consensus (from IQR 0.5 to IQR 1.0). This was attributed to a difference in opinion between the radiography and medical physics participants.

CONCLUSION

- In this study a competence profile for MR radiographers in Malta was established through the collaboration of a multi-stakeholder group of experts.
- The profile can contribute to the establishment of a competence profile for Europe.

Thank you for listening