UNIVERSITY OF MALTA
Institute of Health Care
Radiography Studies

BSc Thesis

"A qualitative comparative study of First Cycle Radiography curricula in a selection of European states with those in Japan with an emphasis on the diagnostic physics component."

Tatsuhito Akimoto
May 2007

DECLARATION

I hereby declare that this dissertation is my own work.

Tatsuhito Akimoto

May 2007

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ACRONYMS USED IN THIS THESIS

HE	Higher Education
ECTS	European Credit Transfer System
MEXT	Japanese Ministry of Education, Culture, Sports, Science and Technology
MHLW	Japanese Ministry of Health, Labour and Welfare
NAID-EU	Japanese National Institution for Academic Degrees and University Evaluation
EQA	External Quality Assurance
JUAA	Japan University Accreditation Association
HENRE	Higher Education Network for Radiography in Europe
VLE	Virtual Learning Environment
C/PBL	Context /Problem Based Learning
CPD	Continuing Professional Development
JART	Japan Association of Radiological Technologists
JSRT	The Japanese Society of Radiological Technology
ISRRT	The International Society of Radiographers and Radiological Technologists
EAR	European Association of Radiology

DEFINITION OF TERMS USED IN THIS THESIS

No special terminology was used in this thesis.

ABSTRACT

Title: A qualitative comparative study of the First Cycle Radiography curricula in a selection of European states with those in Japan with an emphasis on the diagnostic physics component
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Purposes: To compare qualitatively First Cycle Radiography curricula in a selection of European states with those in Japan with an emphasis on the diagnostic physics component.

Methodology: This qualitative survey was conducted via document analysis of the available literature / documentation regarding radiography curricula in Europe and Japan and a series of case-studies of the curricula at selected universities from Europe and Japan. Data for the case-studies was collected with the help of a specially formulated datasheet and appropriate themes elicited from the data. The criteria of choice regarding European and Japanese radiography institutes included: type of programme, general course structure, course objectives/competences, availability of updated information on respective websites and quality of physics curricular content.

Results and conclusions: The main conclusions of the study were: (a) that in Europe, a wide variety of radiography education and curricular structures is still present notwithstanding the efforts of HENRE members to 'tune' such differences. On the other hand in Japan, radiography education structures and curricula appear to be much more uniform owing to the centralised government guidelines regarding radiography education and the nationally determined subject areas of the national radiography examination, (b) in Europe, clinical practice and principles of clinical diagnosis constitute a larger portion of the curriculum than in Japan, underpinning radiography theory and the technological aspects of imaging (physics and medical engineering) are more emphasised in Japan.

1 INTRODUCTION

1.1 INTRODUCTION

This chapter first presents the problem addressed in the study. This is followed by a background to the issues underlying the problem as well as the specific purpose and significance of the study. Databases and keywords used for the literature review are also listed. The chapter ends with an overview of the rest of the thesis.

1.2 STATEMENT OF THE PROBLEM

Although undergraduate radiography programmes are well established in both Europe and Japan, no comparative study has been found in the literature. This is even more so in the case of the biomedical diagnostic imaging physics component of such curricula.

1.3 BACKGROUND TO THE STUDY

Although several comparative studies have been conducted regarding higher education systems, these have been typically conducted between states which have similar cultural, linguistic and educational backgrounds. Few studies have been made between states with totally different backgrounds, such as states within Europe and Japan. Little is found regarding the Japanese higher education (HE) system in the English language literature as only a small fraction of the research conducted by Japanese researchers has been translated into English (Poole, 2003). A thorough search of the literature in fact only produced one comparative study - in the area of nursing curricula (Lambert, Lambert, & Petrini, 2004). In the case of radiography such comparative studies are totally absent. Although, the primary concepts of radiography are universal, content emphasis varies between universities or countries depending on several factors, such as local culture, approaches to professional development and role expansion, educational policies, legal frameworks, regulations, program structure and the actual roles of radiographers in clinical situations (Payne and Nixon, 2001; Pratt and Adams, 2003).

1.4 PURPOSE OF THE STUDY

The purpose of this study was:

1. To review the literature regarding first-cycle radiography programmes in Europe and Japan with an emphasis on the diagnostic imaging physics component of the curriculum,
2. To translate the first-cycle radiography curricula of a selection of Japanese universities with an emphasis on the diagnostic imaging physics component,
3. To qualitatively compare the programmes and in particular the diagnostic imaging physics component of the curricula in a selection of European and Japanese universities. The specific objective of this qualitative study was theme generation, analysis and discussion.

1.5 SIGNIFICANCE OF THE STUDY

For the radiography profession: Know more about and be aware and appreciate programmes of radiography education from other continents.

For radiography educators: Know more about the similarities and differences between radiography education structures and curricula in states in Europe and Japan. This may be particularly useful for HENRE members who are involved in the development of radiography education.

1.6 LIMITS OF THE STUDY

This study involved radiography education at higher education level only.

1.7 LITERATURE DATA AND KEYWORDS

Databases used: Medline, Pubmed, Cinahl and Internet

Keywords: radiography education, health care professional education, radiography physics curricula, imaging physics curricula, Japan.

Important sources of information were the Higher Education Network for radiography in Europe (HENRE) web-site and the websites of the Japanese Ministry of Education, Culture, Sports, Science and technology (MEXT) and the Japanese Ministry of Health, Labour and Welfare (MHLW). Articles from the Japanese Journal of Radiological Technology were also found very valuable.

1.8 OVERVIEW OF THE REST OF THE THESIS

The rest of the thesis deals with the literature review (chapter 2), methodology (chapter 3), presentation, analysis and discussion of results (chapter 4), and conclusions and recommendations for future research (chapter 5).

2 LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter we present a review of the literature regarding higher education, undergraduate radiography education and diagnostic radiography physics education in Europe and Japan.

2.2 HIGHER EDUCATION STRUCTURES IN EUROPE AND JAPAN

2.2.1 The organisation of higher education

Higher education is typically organised within universities and colleges, and follows the completion of secondary education within junior colleges or high schools. The higher education system is generally divided into two structures, the undergraduate (in Europe known as First Cycle) and the postgraduate (in Europe known as the Second and Third Cycles). The undergraduate education systems usually require a minimum of 3 to 4 year study to complete. The modern higher education system includes a huge variety of organisations with different frameworks, objectives, funding systems, qualities and accomplishments. Many countries are still trying to understand and control this highly differentiated educational environment (Altbach, 2003).

In general there are three broad categories of universities:

(1) traditional comprehensive universities,

(2) universities of applied sciences and

(3) specialised universities (Caruana, 2006, personal communication).

Traditional comprehensive universities are the most common type of universities in both Europe and Japan. This type of university covers a wide range of academic areas, and it is often heavily involved in research activities and may give less attention to teaching. However these universities are coming under increasing pressure to improve their teaching services. Admission requirements may be more difficult than those of other types of universities. Examples in Europe are the University of Leeds (England), University College Dublin (Republic of Ireland), University of Amsterdam (the Netherlands), University of Pisa (Italy) and the University of Malta (Malta). Examples in Japan are Osaka University, Nagoya University and Tohoku University.

Universities of Applied Sciences are a relatively new type of university which, contrary to traditional comprehensive universities, are more focused on teaching rather than research (although many of these universities have been conducting funded research recently). Universities of Applied Sciences offer education for the professions - particularly the newer professions (Federal Ministry of Education and Research, Germany, 2003). Examples in Europe are Fontys University of Applied Sciences (Netherlands), Jönköping University (Sweden), University of Salford (England) and University of Ulster (N. Ireland). This type of university is not yet common in Japan. One example is Nagasaki Institute of Applied Sciences.

Specialised Universities are ones that focus on one particular area of expertise (e.g., healthcare). Such universities combine high levels of both teaching and research albeit in a single area of knowledge only. Examples in the case of healthcare are Karolinska

Institutet (Stockholm, Sweden), the Medical University of Vienna (Austria) and the Medical University of Warsaw (Poland). Examples in Japan are Asahikawa Medical College and Tokyo Medical and Dental University.

Degrees in radiography can be found in all type of universities.

2.2.2 Higher education in Europe

The European Higher Education Area

Many EU countries have been united in an attempt to reform their educational frameworks to enhance cross-border recognition of academic degrees and promote smooth exchange of students, educators and professionals. The most notable process in this regard is the construction of the European Higher Education Area (more popularly known as the 'Bologna Process') (Froment, 2003). In 1998, the Sorbonne Declaration was signed by the education ministers of France, Germany, Italy and the United Kingdom in Paris. The Sorbonne Declaration was then followed by the Bologna Declaration, signed by the education ministers of 29 EU countries in Bologna 1999. The Bologna process aims to reform and harmonise the European higher education system (Wende, 2000). At the time of writing, there are 45 countries that participate in the Bologna Process (Communique of the Conference of European Ministers Responsible for Higher Education, 2005).

The objectives of the Bologna process are to establish:

- An educational structure of easily readable and comparable degrees,

- 'Three main cycles', the first cycle ('Bachelor') (undergraduate), the second cycle (Master, graduate) and a third Cycle (Doctoral level) in all EU countries,
- Credit transfer systems, such as ETCS, to promote and increase student mobility and lifelong learning activities,
- Quality assurance mechanisms with similar evaluation criteria and methodologies,
- International interactions of students, educators, academic programmes and research.

Ministerial Summits are organised every two years (Prague, 2001, Berlin, 2003 and Bergen, 2005) to evaluate the process of implementation and the identification of remaining obstacles (The UK HE Europe Unit, 2005). The ministers of education have agreed to continue the stocktaking process and reporting for the next Ministerial Conference in London in 2007. They also confirmed that the Bologna Process is to be completed by 2010 (Communique of the Conference of European Ministers Responsible for Higher Education, 2005).

Tuning

Tuning is a part of the Bologna Process, which focuses on content of studies rather than educational structures. The objective of Tuning is to implement the Bologna Process at the learning level. Tuning aims to identify points of reference for generic (i.e., cross-professional) and subject-specific (Tuning terminology for 'profession-specific') competences (European Commission, 2006). The Tuning process in Europe demands outcome-based curriculum development in which programme outcomes are described in terms of the generic and subject-specific competences that a student should acquire at the end of a programme of studies. These competences are to be agreed by the various stakeholders (academics, professional bodies, future employers, students) at the European level. Curricula are to have a clear practice orientation which would guarantee the employability of graduates. Three phases were developed: Phase I (December 2000 to January 2003), Phase II (February 2003 to December 2004) and Phase III (January 2005 to October 2006). The programme initially focused on 9 subject areas during Phase I and II. Tuning methodology was developed from Phase I and II, it was then applied to other 18 study areas during Phase III. During phase III, which is the most recent phase of Tuning, attention is being given to three areas: (1) validation and consolidation of the outcomes of the Tuning project, which was carried out in Phase II, (2) dissemination and implementation of the Tuning material, and (3) evaluation, monitoring, adjustment and development of the study outcomes (Tuning, 2006). Radiography has been included as one of the Phase III subjects.

2.2.3 Higher education in Japan

The education system in Japan

All schools in Japan are under the control of the Ministry of Education, Culture, Sports, Science and technology (MEXT). These schools are either governmental (national), prefectural (regional) or private. Elementary and lower secondary schools are compulsory education in Japan. Upper secondary education is offered for students who have completed compulsory education and study contents may include 'general' subjects (for students who would be going on to higher education) or 'specialised' subjects (e.g., fisheries, home economics, basic nursing) aimed at students who would not be going on to higher education (MEXT, 2002) (Fig. 2-1). General subjects are offered by Upper Secondary Schools in which students are prepared for examinations of universities (Yoshimoto, 2003). Most students opt for the general subjects at Upper Secondary Schools.

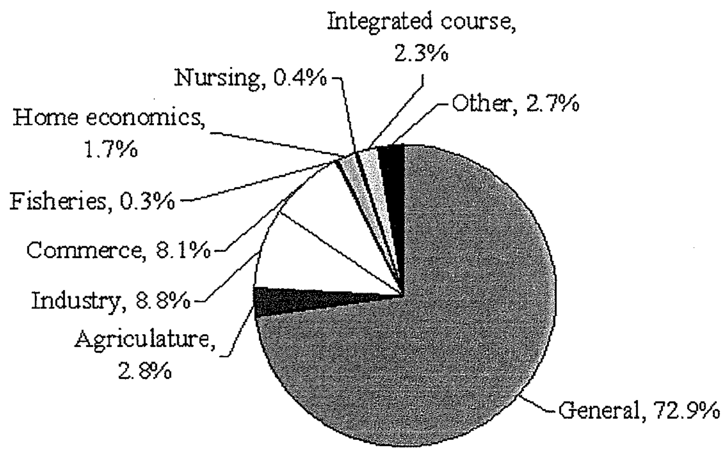


Fig. 2-1 Percentage distribution of study contents in upper secondary education (MEXT, 2002).

The Japanese higher education system is similar to the European university set-up (Fig. 2-2). Completion of Upper Secondary School is the basic enrolment requirement for universities. First level graduates are awarded a bachelor's degree (4 years) accredited by the National Institution for Academic Degrees and University Evaluation (NAID-EU). Students who do not enter university may proceed to junior colleges where the study duration is 2 to 3 years. Colleges of technology are specialised vocational schools where the education structure concentrates on practical skills. The enrolment requirements for Colleges of Technology are a graduation of lower secondary school and the study duration is 5 years. Graduates of junior colleges and colleges of technology are awarded an 'associate' degree which may qualify them for regular university enrolment.

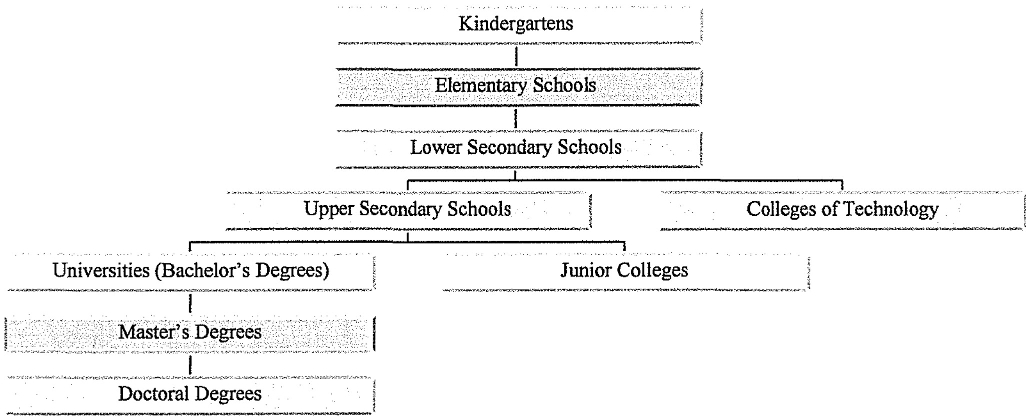


Fig. 2-2 Basic organisations of the school system in Japan

Amendment of the Standards for the Establishment of Universities

In 1991, MEXT announced the Amendment of the Standards for the Establishment of Universities in response to the need for reform of the education system in Japan and also for increasing international competitiveness. In this amendment, two important areas are covered in relation to syllabi/curricula, teaching methods and credit systems in undergraduate level education.

1. Abolition of 'subject areas': Prior to these amendments subjects used to be divided into sub-categories (called 'subject areas') namely common/general fundamental subjects (e.g., physics, mathematics), specialised subjects (e.g., radiography), foreign languages and physical education. These 'subject areas' were removed to allow more flexible curricular development.
2. Relaxation of criteria for credit calculation and course duration: This allows universities to create their own credit calculation systems.

The amendments of the Standards for the Establishment of Universities aims to enable individual universities to establish their own unique and flexible curricula which will satisfy increasing social demands and expectations (MEXT, 1995). Almost all the universities in Japan implemented their amended curricula in the period 1991 to 2004 (MEXT, 2004). However, there has been an argument that, because of the Amendment of the Standards for the Establishment of Universities, in particular the fact that universities are now freer to establish their own curricula, there is a tendency that general subjects are being given less importance than specialised subjects. This seems to be adversely affecting student achievement not only in the general subjects themselves but also in the specialised subjects as the former underpin the latter (Hayashi, 2003).

2.3 RADIOGRAPHY EDUCATION IN EUROPE AND JAPAN

2.3.1 Radiography education in Europe

HENRE

Radiography is one of the subject areas of the Phase III of Tuning and HENRE represents the Socrates thematic network implementing Tuning in radiography. Radiography societies across European countries have realised the differences between radiography education programmes in the different countries. Therefore, HENRE aims to provide opportunities for radiography education institutes, hospitals and European radiography organisations to discuss educational issues and the future professional development of radiographers on a European scale (Challen, 2006). HENRE includes several subgroups, the objectives of each subgroup are summarised in Appendix A. HENRE has provided a forum for radiographers, identified an initial list of subject specific competences for the first cycle programme, researched CPD requirements, teaching and learning strategies, and produced a survey of existing radiography education programmes in Europe.

HENRE survey of existing radiography education programmes in Europe

This survey, in which 47 radiography institutes within 22 EU countries participated, was conducted to evaluate the current radiography education system in Europe. The survey covered a wide range of aspects in European radiography education. The HENRE survey included 11 research areas (see table 2.1) regarding radiography curricula, 4 of which were related directly to curriculum content i.e., 1) physical principles, 2) anatomical, physiological and pathological principles, 3) imaging techniques and 4) professional skills.

Table 2-1 ***Contents of HENRE Subgroup 1 survey data (The various tables summarising the survey data can be found on the HENRE website)***

Table 1 Participating Institutions
Table 2 Qualifications and scope of practice
Table 3 ECTS and Institutions using ECTS
Table 4 Profile of 1st cycle teaching staff
Table 5 Structure of 1st cycle programmes
Table 6 Teaching and learning methods
Table 7 Assessment methods
Table 8 Curriculum content- Physics
Table 9 Curriculum content- A&P&P
Table 10 Curriculum content- Imaging techniques
Table 11 Curriculum content- Professional skills

ESQUIRE

Therapeutic Radiotherapy is an area in which radiographers, physicists and radiation oncologists in Europe have worked together in a concerted and systematic manner and on a European scale to produce curricula and educational materials. An extensive curriculum development programme has been carried out as part of the project ESQUIRE (**E**ducation, **S**cience and **QU**ality Assurance for **R**adiotherapy) which is run under the auspices of the European Society for Therapeutic Radiology and Oncology (ESTRO) and financed by the EC (Europe Against Cancer initiative). Important outcomes of the project included endorsed guidelines for European core curricula for all three professions within radiation therapy i.e., medical physicists, radiotherapists and radiation therapists. It is important to note that, in the case of radiographers the project led to a European core curriculum (Coffey, Degerfalt, Osztavics, Van Hedeld, and Vandervelde, 2004). A weakness of the curriculum is that it is not outcome competence based but simply presents a list of topics to be covered. A copy of the physics part of this curriculum is shown in Appendix B.

2.3.2 Radiography education in Japan

Healthcare profession courses at undergraduate level in Japan are often organised within Departments of Healthcare Sciences in Faculties of Medicine. However junior colleges and specialised training colleges are also involved in radiography education. There are 22 universities, 2 junior colleges and 15 specialised training colleges which are involved in radiography education (Fig. 2-3). *This study will focus on radiography programmes at universities only.*

Credit system in Japanese HE

15 to 30 hours of lecture *or* 30 to 45 hours of experiment/clinical training are assigned to one credit (School Education Law, Standards for Establishment of Universities No.21). Students are required to obtain a minimum of 124 credits for graduation.

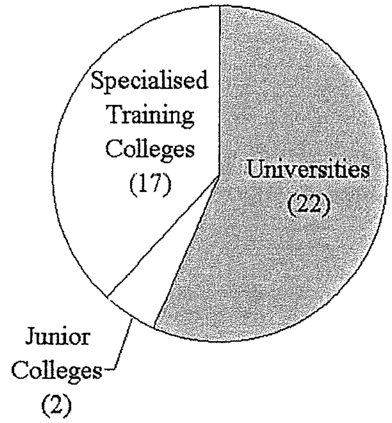


Fig. 2-3 *Academic institutes involved in radiography education.*

National Radiological Technologist Examination

Radiography students have to pass the *national* radiological technologist examination which is under the control of the Ministry of Health, Labour and Welfare. This is in direct contrast to universities in Europe where examinations are the prerogative of the university concerned. Candidates must have completed a minimum of 3 year education at a radiography institute in order to sit for the examination (School Education Law No.56-1 and Medical Radiological Technologist Law No.20).

In 2003, the Medical Radiological Technologist law was implemented with respect to the education of radiological technologists (Nishio, 2003). This introduced new educational requirements related to new imaging modalities such as MRI, changes in the names of the examination subjects and the addition of new subject areas in response to the rapid developments in new medical imaging modalities and changing roles of radiological technologists. Subjects in the national examination for radiological technologists are listed in Table 2-2. As radiation therapy is included in this curriculum Radiography programmes in Japan, unlike in Europe, are *always* combined Diagnostic and Therapeutic programmes. The addition of new subjects to the national examination, such as medical image information technology and radiation safety control reflects demands by hospital management, Japanese society and the developments of occupational standards in radiography (Nishino, 2003).

Table 2-2 *Subjects in the national radiological technologist examination.*

- General medicine
- Radiation biology (includes radiation hygiene i.e., radiation protection)
- Radiation physics
- Radiation chemistry
- Medical engineering
- Medical imaging instruments
- Radiographic techniques
- Medical imaging technology
- Imaging engineering
- Medical informatics
- Radiation measurement
- Nuclear medicine
- Radiation therapy
- Radiation safety control

The MEXT (2000) guideline for radiography curricula are shown in Table 2.3 . However it should be noted that this guideline gives only very loose descriptions of study areas and does not specify the study contents.

Table 2-3 *Study units in Japan specific to radiography education (MEXT, 2000)*

	Subject Areas	Credits	Objectives
General Subjects	Scientific Perspectives Human Life	14	• Cultivate scientific and logical thinking, understand human nature, and flexible but independent judgements and actions • Understand bioethics and human dignity • Cultivate the ability to cope with globalisation and information age
	Subtotal	14	
	Human Structures, Functions and Diseases	12	• Understand human structures, functions, diseases and other related topics • Understand public health and societies

Basic Specialised Subjects	Basic Science and Radiological Science/Technology	18	• Cultivate basic knowledge and the ability to learn healthcare, medicine and welfare related to science and information technology • Cultivate basic knowledge necessary for the safe use of radiation in healthcare, medicine and welfare
	Subtotal	30	
Specialised Subjects	Radiographic Techniques	17	• Understand imaging principles, mechanical structures, quality assurance, radiographic techniques, analysis and evaluation of images in XRI, CT, MRI and USI
	Nuclear Medicine	6	• Understand imaging principles, mechanical structures, quality assurance, radiographic techniques, analysis and evaluation of images in RNI
	Radiotherapy	6	• Understand imaging principles, mechanical structures, quality assurance, radiographic techniques, analysis and evaluation of images in radiotherapy
	Medical Image Information System	6	• Understand theories for image acquisition, construction, analysis, evaluation and medical information network system
	Radiation Safety and Management	4	• Understand the safe use of radiation and its related regulations and laws as well as safety management of radiation in healthcare
	Clinical training	10	• Cultivate radiographic techniques in clinical situations and understand radiology department management, patient care and responsibilities of radiographers as a part of a medical team
	Subtotal	49	
Total		93	

2.4 DIAGNOSTIC RADIOGRAPHY PHYSICS EDUCATION IN EUROPE AND JAPAN

2.4.1 Diagnostic physics education in Europe

The directory of radiography programmes in Europe published by HENRE (2006) includes information on the physics component. The results (see Table 2-4) show that basic principles in radiation physics study contents (i.e., basic structures and operations of modalities and radiation protection concepts) are considered to be of high importance at all universities.

Table 2-4 Curriculum content of physical principles for first cycle radiography programmes in Europe (HENRE Subgroup 1, 2006)

Town/City	3a	3b	3c	3d	3e	3f	3g	3h
Innsbruck	E	E	E	E	E	E	E	E
Neustadt Wr	E	E	E	E	E	E	D	E
Brussels	E	D	E	E	E	NR	D	D
Frankfurt	E	E	E	dna	E	E	E	E
Oldenburg	E	E	E	E	E	E	E	E
Dresden	E	E	D	E	E	E	E	E
Copenhagen	E	E	E	E	E	D	E	E
Aalberg	E	E	E	E	E	NR	E	E
Odense	E	E	E	E	E	D	E	E
Tallinn	E	E	E	E	E	E	E	E
Athens	NR	NR	NR	NR	NR	NR	NR	NR
Athens	E	E	E	E	E	E	E	E
Oulu	E	E	E	D	E	E	E	E
Tampere	E	D	E	E	E	E	E	E
Helsinki	E	E	E	E	E	E	E	E
Paris	E	D	E	E	E	E	D	D
Franconville	E	E	D	D	E	E	E	E
Semmelweis	E	E	E	E	E	D	E	E
Pecs	E	D	E	D	D	D	D	E
Dublin	D	E	E	E	E	NR	D	E
Rekjavik	E	E	E	E	E	E	E	E
Florence	D	D	D	D	D	D	D	D
Vilnius	E	E	E	E	E	E	E	E
Valetta	E	E	E	E	E	NR	D	D
Fontys	E	E	D	E	E	E	D	E
Haarlem	E	E	E	D	E	E	E	E
Oslo	NR	E	NR	E	E	NR	NR	E
Trondheim	E	E	D	D	E	E	E	E
Tromso	E	D	D	D	E	E	E	E
Lodz	D	D	E	E	E	E	NR	NR
Gdansk	E	E	E	E	E	E	E	E
Coimbra	E	D	E	E	E	NR	E	E
Umea	E	E	E	E	E	NR	E	E
Stockholm	D	NR	D	D	D	NR	D	D
Jonkoping	E	E	E	E	E	NR	E	E
Orebro	E	D	D	NR	E	D	E	E
Vakjo	E	E	E	E	E	NR	E	E
Goteborg	E	E	E	E	E	NR	E	E
Martin	E	E	E	E	E	E	E	E
Ljubjana	E	E	E	E	D	E	D	D
Ankara	D	E	E	E	E	E	E	E

Salford	E	E	E	E	E	E	E	E
Lancaster	E	E	E	E	E	E	E	E
Hatfield	E	D	E	E	E	NR	E	E
Aberdeen	D	D	D	D	D	NR	D	E
Edinburgh	D	D	E	E	E	NR	E	E

3a – Image acquisition equipment (CT, MRI, Plain film)
3b – image generating equipment (laser printer, TV monitor)
3c – Film processing equipment
3d – Film/image rejection
3e – Dose reference and measurement
3f – Radiotherapy equipment
3g – Clinical practice audit/evidence based practice
3h – Reflection on practice
E – Essential, D – Desired, NR – Not required

Only one study regarding first cycle diagnostic physics education in Europe was found in the journal literature (Caruana & Plasek, 2005). The result of the study revealed that the role of *diagnostic* radiography physics curricula in Europe is to ensure that students acquire the underpinning physics required to support the following radiography Subject Specific Competences:

- Understand the key concepts of the physical sciences that underpin medical imaging and be able to utilize them in their practice and research.
- Be able to use medical imaging and ancillary devices effectively, safely and economically within their specific scope-of-practice.
- Be able to practice in accordance with legislation governing the use of radiation for medical imaging purposes.
- Be able to audit, monitor and review the effectiveness, safety and economic aspects of practice and modify it accordingly.

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-competences which underpin the above broad subject specific competences and which should therefore be addressed in radiography curricula. The inventory is given in Appendix C. It is to be noted that the curriculum was developed in cooperation with HENRE partners and should form a good basis for a future European curriculum.

2.4.2 Diagnostic radiography physics in Japan

No similar works as the above have been found for Japan. This could be because the curriculum is centrally determined by the guideline from MEXT and the national examination subject areas from MHLW. However it should be noted that neither of these specify in detail the content to be included in radiography physics curricula. A survey similar to the one conducted by HENRE would help a lot in uncovering the extent of homogeneity or otherwise of Japanese curricula in real practice. Ohba, Ogasawara & Aburano (2004) did make a study of radiation safety education at radiography institutes in Japan. The survey data showed that there is no significant difference of educational structures, curricula and facilities with regard to radiation safety education.

3 METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the methodology used in the study.

3.2 RESEARCH APPROACH

The research approach of the study was primarily qualitative. A research approach is qualitative when the overall purpose is theory generation as opposed to quantitative theory confirmation. Findings can be concepts (often known as 'constructs'), themes, categories, typologies, or tentative hypotheses. Qualitative methods are essential in studies which are fundamentally exploratory in nature, that is, when very little is known about the area of research as in the case of this study. Qualitative research is inductive and inferences are developed in cumulative increments based on data acquired during each stage of the study. In qualitative research, data is not collected via randomised sampling but via purposeful sampling, that is cases are chosen according to the *purposes of the study. The purpose of our study was theme generation and analysis*. Data collection was stopped in this study when few significant themes were emerging. This is known as data saturation.

3.3 RESEARCH STRATEGY

A literature search regarding radiography curricula in Europe and Japan and a qualitative survey consisting of a series of case-studies of the programmes / curricula at selected universities were used to conduct this comparative study. A qualitative case-study approach enabled an in-depth study and analysis of radiography education structures at the selected universities. Universities with radiography programmes in Europe and Japan were initially surveyed using the Internet. A total of 6 universities were then chosen for this comparative study. The criteria of choice of European and Japanese radiography institutes included: type of programme (only universities having both diagnostic and therapeutic programmes were chosen), general course structure, course objectives/competences, availability of updated information on respective websites and quality of physics curricular content. These criteria were established so that a wide variety of radiography education systems and curricula could be studied hence ensuring that the most significant themes are detected. Course curricular documents were obtained from Tromso University College (Norway), University of Portsmouth (UK), Queen Margaret University College (UK), Fontys Hogescholen (The Netherlands), Osaka University (Japan) and Nagoya University (Japan). Four European radiography courses were chosen from different areas in Europe to include different types of course structures as radiography education in Europe is at the moment still quite heterogeneous. Two National universities located in large cities in Japan were chosen for this study as together they represented the range of thematic issues of the higher educational system set-up for radiography in Japan. Two universities were sufficient in the case of Japan since the curriculum is centrally determined and therefore there is a higher level of homogeneity than in Europe. However the programmes of some other universities which supplied new individual themes (but which however did not warrant a full case-study) were also noted.

3.4 DATA COLLECTION TECHNIQUE

The main data collection techniques in case-study research are document analysis, direct observation during on-site visits and interviews (Creswell, 2003, p. 187; Yin, 2003, p.

86). The data collection technique used during this study was document analysis. Document (published documents, syllabi, course descriptions and curricula) data was obtained from the general literature, official government and university web-sites or via email from course leaders.

Document analysis provides several advantages over other techniques for this particular study:

- Public documents represent data which has been given thoughtful attention by the authors since they are expected to be seen by many people (students, researchers, educators etc).
- The technique is unobtrusive and avoids the biasing of responses or observations created by the researcher's presence during interviews and direct observations (McKernan, 1996 and Creswell, 2003).
- High availability of documents since curricula are public documents.
- High accessibility of web-site documents - can be accessed at any time convenient to the researcher.
- As written evidence documents save on transcribing time and expense.
- Course descriptions, syllabi and curricula of academic institutes tend to follow similar formats which allow easier formulation of comparative themes.

3.5 THE THEME COLLECTION INSTRUMENT

Data was collected with the help of a purposely-designed theme collection instrument. All sections included a column for noting themes that could be inferred from the data. The thematic datasheet was piloted during the first case study and subsequently improved recursively as new themes emerged.

The theme collection instrument was subdivided into 3 sections:

The first section contained basic information on the educational programme as a whole and on the context in which the programme is carried out: country, city, name of university, type of university, name of programme, academic title awarded, duration, registration (if the programme is approved for registration in the country), type of course (combined or separate diagnostic / therapeutic programmes), number of credits required for graduation, curriculum philosophy and orientation (e.g., diagnostic vs. technological) and programme structure.

The second section describes the general curriculum content, imaging modalities studied, teaching methodology and methods of assessment. The curriculum content was classified under the headings Human biology, Biomedical physics/engineering, imaging/therapeutic protocol design, Imaging practice and Supportive subjects. This was done in order to be able to assess the importance given to the various aspects of the curriculum. The number of credits assigned to each subject is also shown in this section.

The last section deals with academic topics in diagnostic radiography physics education. This section emphasises actual physics content rather than unit / module titles. In order to assess the importance given to the various components of the physics curriculum at the various universities the physics study contents were further subdivided into subcategories as shown in Table 3.1.

Table 3.1 – Subcategories of physics study contents

Subcategory	Study contents included in the subcategory.
Basic physics	• Basic diagnostic radiography physics • Basic therapeutic radiography physics • Basic medical engineering • Radiochemistry
Device structure and functioning	• Structures and functioning of the various imaging modality devices including radiation production, detection and image display. • Structures and functioning of therapeutic modality devices
Safety including radiation protection	• Radiobiology • Radiation hazards • Patient and occupational radiation protection • Radiation dose measurement • Safe handling of radioactive materials • Laws, regulations and local rules regarding radiation protection
Quality control	• QC of diagnostic and therapeutic devices • Image quality outcomes • Imaging / Therapeutic device performance indicators • Evaluation of radiographic and therapeutic devices • Documentation and analysis of QC programmes
Digital imaging processing	• Image processing in digital radiography • Algorithms • Image manipulation and enhancement
Film processing	• Film processing (wet and dry processors) • Darkroom and daylight systems

3.6 DATA ANALYSIS

The filled in thematic data sheets were analysed and several themes related to the study were inferred from the data. These themes were inventorised and subsequently analysed and discussed in depth.

3.7 LIMITATIONS OF THE RESEARCH DESIGN

The methodological limitations of the study arise from limitations of the research design used. Qualitative research has been criticised for its use of non-representative non-random samples. *However this type of criticism arises from a misconception of the purposes of qualitative research.* Qualitative research is more interested in uncovering the range of themes relevant to an issue than the number of participants holding a particular thematic point of view.

This study was conducted without direct on-site observations/interviews and based purely on documents publicly available from academic institutes. Such documents may not be complete or may not accurately describe the current situation. To reduce the effect of the latter only universities with updated websites were included in the sample.

It is also acknowledged that although we believe that the sample was sufficient to supply most of the relevant themes, the inclusion of more universities would perhaps uncover further themes.

3.8 ETHICAL CONSIDERATIONS

Documents used in this study are public documents available from university websites and bookshops. It is the view of the researcher that analysis of the practice of others is above all the discernment of what is good and essentially an inventory of good practice. Any negative aspects are reported in a way that the particular universities cannot be identified.

3.9 CONCLUSION

This chapter presented the overall research methodology and described and discussed the theme collection instrument used during this study. In the next chapter, each theme will be analysed and discussed based on the data obtained from the theme collection instruments.

4 RESULTS, ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the analysis and discussion of the themes regarding similarities and differences in European and Japanese radiography education derived from the data. Special attention is given to a comparison of the study contents in diagnostic imaging physics curricula.

4.2 RESULTS

The filled-in datasheets for the universities under study can be found in the following appendices.

Appendix D: Tromso College

Appendix E: Fontys Hogeschollen

Appendix F: Portsmouth University

Appendix G: Queen Margaret University College

Appendix H: Nagoya University

Appendix I: Osaka University

4.3 INVENTORY OF THEMES ARISING FROM THE RESEARCH DATA

The following is the list of themes established from the research data:

1. Type of university hosting the department of radiography
2. Location of the radiography department within the university structure

3. Academic title awarded to graduates of the radiography program
4. Curriculum content determination (i.e., whether school based or nationally set)
5. Duration of study program
6. Structure of credit system
7. Type of program (i.e., whether separate diagnostic / therapy or combined)
8. Curriculum philosophy and orientation (e.g., whether technology oriented as opposed to clinical diagnosis oriented)
9. Overall program structure
10. Curriculum content (credits allotted to the following parts of the curriculum)
    a. Human biology (i.e., anatomy, physiology, pathology)
    b. Biomedical physics / engineering
    c. Imaging / therapeutic protocol design
    d. Clinical practice
    e. Supportive subjects
11. Modalities (diagnostic / therapeutic) taught
12. Teaching methodology
13. Diagnostic radiography physics curricula:
    a. Basic Physics
    b. Device structure and functioning
    c. Safety including radiation protection
    d. Quality control
    e. Information technology
    f. Digital image processing

g. Film processing

4.4 ANALYSIS AND DISCUSSION OF THE THEMES

4.4.1 Type of university hosting the department of radiography

Many radiography institutes in Europe are organised either in Traditional Comprehensive Universities or Universities of Applied Sciences. It appears that Universities of Applied Sciences are becoming common in Europe. In Japan, the majority of radiography courses are organised within traditional comprehensive universities (e.g. Osaka University, Nagoya University, Teikyo University and Tokyo Metropolitan University) but a few courses belong to public specialised medical universities (e.g. Suzuka University of Medical sciences and Hiroshima prefectural College of health sciences). Universities of Applied Sciences are not yet common in Japan.

4.4.2 Location of the radiography department within the university structure

In Europe radiography courses are organised under different faculties. For example, the radiography department at Portsmouth University is a part of the Faculty of Science, whilst the department at Tromso University College is part of the Faculty of Health Sciences. On the contrary, in Japan, the radiography departments at the universities studied belong to Faculties of Medicine although the Faculties of Medicine are divided into a medical school and a school of health sciences. This means that in Japan radiography seems to be much more tightly linked to medicine than in Europe. Both Japanese universities studied were *national* universities. However, we have noted that in *private* universities, there is a tendency for radiography courses to be independent of the Faculty of Medicine (for example, Teikyo University, - Faculty of Medical Technology, and Kitazato University - Faculty of Medical Engineering). More variations may be seen in the future because of the recent reform of the radiography education system and the increase in newly established radiography institutes.

4.4.3 Academic title awarded to graduates of the radiography programme

In Japan, radiography graduates are awarded BHSc (Bachelor of Health Science). The reason for this is that in Japan the "pure sciences (physics, chemistry, biology and mathematics" and "health science" are completely separated areas of study at the undergraduate level. BHSc is hence considered a more appropriate academic title for radiography students than BSc (Bachelor of Science). On the other hand, BSc is the preferred academic title in Europe. This may be an indication that, perhaps in Europe an association with the pure sciences carries more prestige.

4.4.4 Curriculum content determination

In Japan, the subject areas of the national examination for radiographers are determined centrally and published by the Ministry of Health, Labour and Welfare and the curriculum guideline for radiography institutes is set by MEXT. This is in direct contrast to the European universities studied which have a much higher control of the curriculum content, albeit in some countries within guidelines set by educational quality assurance authorities (e.g., the Quality Assurance Agency, QAA in the United Kingdom).

4.4.5 Duration of study programme

The duration of study programmes in Europe varies between 3 to 4 years. For example, Tromso College and University of Portsmouth are 3 year courses, while Fontys Hogescholen and Queen Margaret University College are 4 year courses. This is independent of whether they are separate diagnostic / therapy or combined courses. All undergraduate radiography courses are 4 year programmes in Japan.

Duration of study programme and type of programme structure are important factors which determine study contents and study hours when formulating curricula.
The weakness of 3 year programmes, when compared with 4 year programmes, is the fact that the programmes must compensate for the shorter duration of study programme by selectively choosing study content owing to the obvious reduced lecture/training hours. 3 year programmes are either diagnostic/therapeutic combined (Tromso) or separate (Portsmouth). In the case of 3-year-combined type of programmes, lecture/training hours which can be dedicated to any of the two variants of radiography are obviously far less than those in 4-year separate diagnostic / therapeutic programmes. A good programme for continuing professional education (CPE) may be necessary to overcome this weakness in 3 year programmes. On the other hand combined programs offer entry to the whole range of radiography practice. In Japan, academic programmes at the undergraduate level have to be 4 years in order to provide enough credits for a graduation (this is further discussed in the next section). Nearly all the undergraduate radiography courses have been upgraded to 4 years. This upgrade was necessary since new curriculum contents have been added to programmes and the role of radiographers is expanding.

4.4.6 Structure of credit system

Despite the effort made by the Bologna process and HENRE, different credit systems are still used in Europe. The results of a survey conducted by HENRE (2006) are shown in Appendix J. The table shows that the study hours assigned to 1 ECTS and the total number of ECTS necessary for graduation vary greatly between European radiography programs. At Queen Margaret University College, 480 credits are necessary for graduation but this is calculated at 1 credit = 10 hours of study. At Tromso University College 180 ECTS are required for graduation, where 1 ECTS = 27 hours of study. In Fontys Hogescholen, the Dutch credit system is still used. 40 hours of study per week is equal to 1 credit point, and 168 credit points are required to qualify from the programme. 168 Dutch credit points are equivalent to 240 ECTS (where 1 ECTS=27 hours of study).

In Japan, according to the School Education Law and guidelines from MEXT, one credit is given to 15-30 hours of lectures or 30-45 hours of practice/experiment/clinical training respectively. Usually, one credit is given to15 hours of lectures, 30 hours of on campus practice and 45 hours of experimental/clinical training. Students are usually required to obtain about 120 credits to graduate (typically 124 credits).

Before the Amendment of the Standards for the Establishment of Universities, generally 30 hours of lectures was assigned to one credit instead of 15 hours. This drastic change has affected two aspects in Japanese radiography education: educators need to revise their teaching methodologies in order to maintain all the necessary study content and quality of lectures within half of the previous number of study hours and students are now expected to conduct independent study. This change was initially introduced in medicine and it has been successful - the study content, education quality and student's knowledge have been maintained while more hours are assigned to clinical training (Matsuhmoto, 2004).

4.4.7 Type of program (i.e., whether separate diagnostic / therapy or combined program)

Diagnostic/Therapeutic combined types of programmes are the more common in most countries in Europe. Exceptions are mainly the UK (e.g., Portsmouth University and Queen Margaret University), Republic of Ireland, Malta and Portugal (Caruana C. J., personal communication). Since curricula and examinations in Japan are centrally determined (see Section 4.4.4) and these include both diagnostic and therapeutic components it is natural that all radiography programmes in Japan are the combined type. The final educational goal of all the radiography courses in Japan is to educate students so that they will pass the national examination for the radiographer's qualification which includes both diagnostic and therapeutic components.

4.4.8 Curriculum philosophy and orientation

General curriculum philosophy at all universities is to develop students' skills and knowledge in radiography as well as their professional behaviour toward patients and other healthcare workers. International exchange and contribution of radiographic skills and knowledge are also emphasised at some institutes (Tromso College and Nagoya University). However we have noticed that in Japan the curriculum *is more physics /*

engineering / technology oriented than diagnosis oriented as seems to be the trend in Europe (Fig 4.1 and see also 4.4.10 for further discussions). This trend towards physics / engineering / technology might in fact be increasing. One typical example is seen in the case of Komazawa University. The Komazawa University, Department of Radiology Science, Faculty of Health Science, offers a 4 year degree course in radiography which aims to contribute to further developments in the physics-engineering aspect of radiography (Komazawa University, 2003; Koyama, 2003). In addition to the regular radiography content, students also study theory of digital images, image network technology and image transmission theory, algorithms for medical image processing and theories of individual imaging modalities. Furthermore, the course is divided into 2 groups after a 2-year common education: diagnostic imaging science and image engineering science. In image engineering science, the education aims to produce radiographers who can work with medical image networks and their management. Radiographers with expertise in medical image engineering, computer networks and medical image management on top of the normal radiographic studies and clinical practice are currently much in demand in the Japanese healthcare industry (Takano, 2003).

4.4.9 Overall programme structure

In Europe different types of programme structures are found. The University of Portsmouth uses a block system in which theoretical lectures, clinical training, tutorials and group discussions are combined. Special attention is given to clinical training which starts at an early stage of the programme and constitutes about 50% of the programme.

Although diagnostic and therapeutic radiography are separated at University of Portsmouth, students from both courses and other healthcare courses interact with each other to obtain "cross fertilisation of knowledge". At Tromso College, the programme is divided into 6 modules (where each module corresponds to one semester, for example, Module 4: General imaging and nursing and Module 5: Oncology and radiotherapy treatment, see also Appendix D). At Fontys Hogescholen, the course is divided into two parts: *Propedeuse* (the first year of the programme) and *post-propedeuse*(the second, third and final years). Students must take and pass the preliminary examination in order to proceed into the *post-propedeuse*. At Queen Margaret University College the first year of the programme serves to introduce students to basic concepts of healthcare and science-based technologies such as human biology, communication and psychology which provide the academic information necessary for later stages in the programme. Students spend the rest of the years on clinical training and more advanced radiography studies.

Radiography students at Osaka University spend the first period of the programme (1.5 year) on learning "general subjects" and "specialised subjects" (See Appendix I). This is a preparation period providing students with a wide range of academic knowledge which is considered necessary for later radiography education. In this period, radiography students also have an opportunity to interact with students from other faculties and departments. Radiography education starts from the second semester of the second year (although a few subjects related to radiography are taught during the first period of the programme). This is a typical programme structure in Japan which is also seen in Nagoya

University and other radiography institutes. The Module/Block system is not used in Japan.

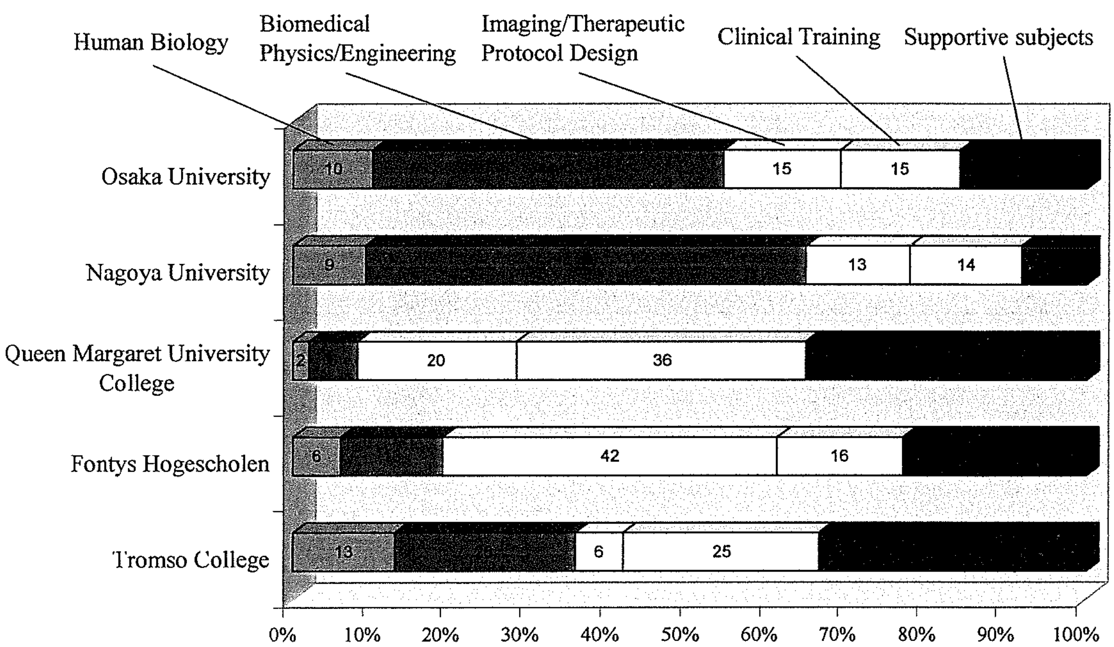
4.4.10 Curriculum content

This section describes and compares credit distributions within the different major sections of the curriculum (i.e., human biology, biomedical physics/engineering, imaging /therapeutic protocol design, imaging practice and supportive subjects, see also table 3.1) of the curriculum in the different universities (Fig. 4.1). In Japan, curricular structures at radiography institutes are very similar to each other as they are recommended to follow the guideline from the MEXT and MHLW and the subject areas of the national examination for radiographers (Fig. 4-2, 4-3 and Appendix H, I and Matsumoto, 2000-2001). Much greater variations are observed at European radiography institutes (Appendix D-G).

Human biology: Subjects in Human Biology are generally taught at a relatively early stage of programmes in both Europe and Japan as they are necessary prior to more advanced studies and constitute the basic part of radiography education. These subjects occupy about 10% of curricula on average. Topics in Human Biology, particularly radiographic anatomy may be included in other parts of curricula (for example, anatomy is taught or revised in imaging/therapeutic protocol design).

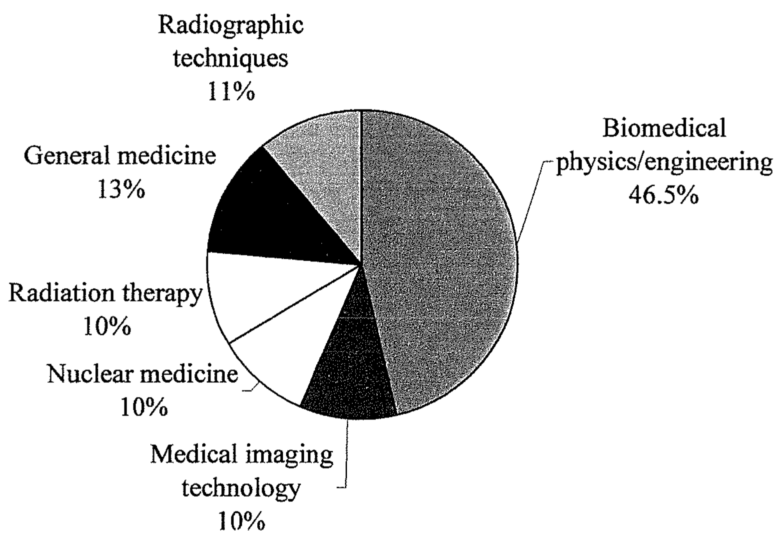
Biomedical physics/engineering: It is interesting to note that radiography education in Japan is more heavily based on biomedical physics/engineering than in Europe. At the two Japanese radiography institutes studied (Nagoya and Osaka), study content in biomedical physics/engineering occupies about 50% of their entire curricula. Theoretical lectures of biomedical physics and engineering are often followed by experiments. This is one of the major characteristics of Japanese radiography education. It appears that this characteristic curricular structure in Japan is developed according to the subject areas in the national examination for radiographers (Fig. 4-2) and the guideline from MEXT and MHLW (Fig. 4-3). In Europe, basic study content in biomedical physics is covered, but engineering aspects and associated experiments do not appear to be common. This topic will be discussed further in section 4.4.13.

Fig. 4-1 Credit distributions in radiography curricula



Note: at Queen Margaret University College, topics related to Human biology are often included in other parts of the curriculum. There is only one subject (Introduction to the human body: 10 credits) which is *specifically dedicated to Human biology study (University of Portsmouth is not included in this section since the total number of credits necessary for a graduation could not be found in the curriculum). Biomedical physics/engineering includes radiation physics, medical engineering, medical imaging instruments, medical informatics, medical imaging engineering, radiation biology, radiation chemistry, radiation measurement and radiation safety control.*

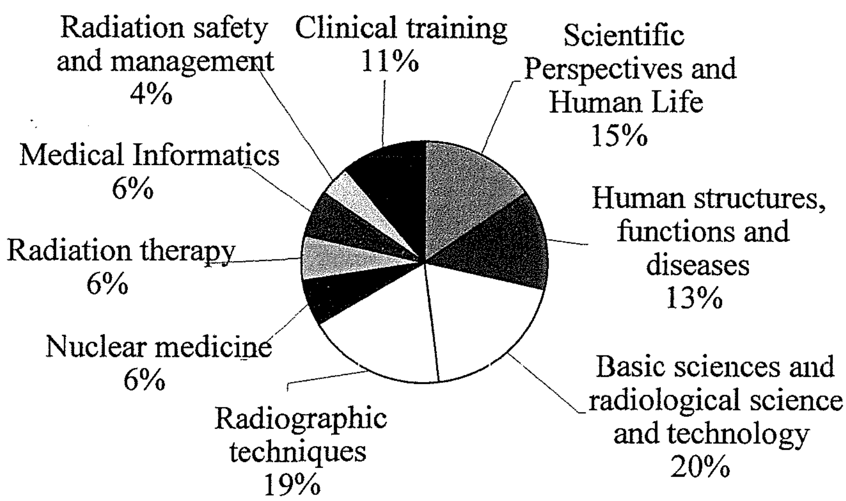
Fig. 4-2 Subject area distribution in the national examination for radiographers in Japan (MHLW, 2005 and Suzuki, S., 2007)



Imaging and therapeutic protocol design: This generally refers to theoretical lectures on how to image patients with different clinical conditions in each modality or the study of therapeutic protocols. The number of credits allotted to imaging and therapeutic protocol design varies between radiography institutes in Europe (Fig. 4-1 and Appendix D-G) . In Japan, about 15% of the curriculum is allotted to imaging and therapeutic protocol design study (Fig. 4-1).

Clinical training: Clinical training constitutes a large part of curricula in Europe (about 50% of the curriculum is assigned to clinical training at University of Portsmouth) and it is usually spread throughout the programme. In Japan, much less emphasis is made on clinical training than Europe and it tends to be done at a late stage of the programme (in the third and fourth years). Fig. 4-1 reveals that radiography education in Europe places more emphasis on clinical-practice than in Japan.

Fig. 4-3 Subject area distributions in the guideline of curricula and study contents for radiography education (MEXT and MHLW, 2000).



Study content in biomedical physics/engineering (including Basic sciences and radiological science and technology, Medical informatics and Radiation safety and measurement) constitutes 30% of the guideline.

Supportive subjects: These subjects are typically related to radiography patient care (e.g. patient care, communication, inter-personal skills, psychology/sociology). Large parts of curricula are allotted to supportive subjects in Europe. On the other hand, in Japan, this is a minor part of radiography education (Fig. 4-1). This may indicate that the concept and awareness of patient care in Europe is more advanced than in Japan. However it seems that in Europe these subjects have been introduced *at the expense of more technological aspects - an issue which may affect the future technological competences within the profession as a whole within Europe. This is an important concern which may perhaps need to be researched in future.*

4.4.11 Modalities (diagnostic / therapeutic) taught

Survey data of HENRE Subgroup 1 (Appendix K) and available curricula show that basic diagnostic imaging modalities such as general radiography (including mammography and fluoroscopy), CT, MRI, US and RNI are generally covered and there is no notable difference between Europe and Japan, although actual study contents in curricula vary depending on radiography programme structures and curriculum orientation. Exact identification of therapeutic modalities could not be carried out due to the lack of detailed information available from the curricula and documents.

4.4.12 Teaching methodology

Teaching methodologies in radiography education generally include lecture, tutorial, seminar, workshop, clinical training, e-learning and PBL. These terms are defined by HENRE Subgroup 2 (Appendix L). All European radiography institutes, which surveyed in this study, have adopted most of these teaching methods to a greater or lesser extent, though many European radiography institutes have never used e-learning (35%) and PBL (30%) (HENRE Subgroup 2, 2005, See Appendix M). Lectures, seminars, small group discussions are the most commonly used teaching methods in both Europe and Japan. No information regarding e-learning and PBL in radiography education in Japan was found (although e-learning and PBL are becoming common in Japanese higher education especially in medicine and nursing). There are only a few studies on long-term outcomes of PBL in Japan and its impact on professional development is still unknown (Matsui, 2003).

4.4.13 Diagnostic radiography physics curricula

It was observed from the curricular documents of the radiography institutes under study that though the physics part of radiography physics education is similar in both Europe and Japan, different approaches to radiography physics curricula are also seen at each institute. In this section, the differences and similarities of physics study contents as well as characteristic physics curricular structures in Europe and Japan are presented and discussed.

Basic physics

Basic radiography physics comprises one of the essential study areas in radiography education where students develop knowledge in the basic physical properties for understanding the effective and safe use of medical imaging devices (ionizing/non-ionising). In Europe and Japan, study contents in basic physics generally include the structure of the atom, production of x-rays, basic structures of the x-ray tube, different types of image receptors, interaction of radiation with matter, parameters affecting image quality outcomes, radioactivity and image formation processes. Even when diagnostic and therapeutic programmes are separate (e.g., University of Portsmouth and Queen Margaret University College), most of these study contents are shared by the two programmes.

However, a significant difference was noted between European and Japanese study contents in this category. Rich study contents in the physics of medical engineering such as electric circuit theory, solid state physics and medical optics are included in the curriculum of Osaka and Nagoya Universities. In the national examination, 9% of questions are related to medical engineering (Medical engineering and Medical imaging), and possibly more since other questions require background knowledge in medical engineering (e.g. Medical imaging instruments and Radiation measurement). On the other hand, no study content in medical engineering was found from the sample curricula in Europe. The specific reasons for this difference in study contents between European and Japanese curricular structures could not be identified with certainty in this study. However one should definitely note that Japanese society does in general value and hold in high esteem advanced technological competence and that in Europe role expansion may be moving more in the direction of diagnostic reporting. Further research in this area is required.

Device structure and functioning

Device structure and functioning is an important study area in radiography physics. Basic principles of operation of the imaging modalities and associated devices found in radiology departments are taught. Generally, the educational objective in device structure and functioning is to ensure that students will apply their knowledge of basic physics to the understanding of medical image production. Study contents in device structure and functioning include physical structure and image acquisition systems of general projection radiography, CT, MRI, US, RNI, dental radiography and mammography in diagnostic radiography. Similar curricula are observed in European and Japanese curricula in this study area, although study contents in device structure and functioning greatly differ when diagnostic and therapeutic radiography are separate (e.g., UK). When a programme is designed for diagnostic or therapeutic only, more in-depth study contents can be found for the particular form of radiography. At Nagoya and Osaka Universities, relatively new study areas such as PET/SPECT physics are also found in the curricula.

Safety including radiation protection

Study contents in radiation safety management cover a wide range of topics in both Europe and Japan. Topics in this category include radiation biology, patient/occupational radiation protection, safe handling of pharmaceuticals, design of radiology departments/examination rooms, radiation chemistry, and laws/regulations concerning radiation protection. These are standard study contents found in both Europe and Japan. A slight difference was observed in the separate type of programmes (UK), where different study contents are developed depending on the nature of the course (diagnostic or therapeutic). A lot of emphasis is made on legal and regulatory aspects of radiation safety control in Japan. Japanese laws and regulations concerning medicine, healthcare, radiation protection, handling of radioactive isotopes and prevention of radiation hazards are taught in lectures. It should be noted that in Japan, ICRP recommendations are widely acknowledged and Japanese laws/regulations as well as ICRP documents are used as references in lectures (e.g., there is a question about ICRP directives in the 2006 national examination). Radiation safety education does not seem to be experiment based in either Europe or Japan. In Japan this is due to the reduced study hours (since the introduction of the Amendment of the Standards for the Establishment of Universities), insufficient numbers of educators with expertise in radiation safety and insufficient facilities (Ohba, 2004). Another reason probably is that radiation safety management constitutes the smallest part in the guideline from MEXT (Fig. 4-2).

Quality control

A similar curricular structure in device Quality Control (QC) is seen in Europe and Japan. Radiography students learn the importance of measurements of imaging device performance indicators, documentation of test results and evaluation of image quality outcomes. Whether study contents include the QC of specific diagnostic modalities is not explicitly found in the curricula (except for Nagoya University). The guideline from MEXT and the subject areas of the national examination do not include QC, although many study contents and some questions related to QC in the national examination have been found.

Information technology

Information technology is a new study area in radiography curricula. Basic computing and computer network systems are becoming standard academic topics. Application of software and hospital data processing and management are also typically included. In the UK, where diagnostic and therapeutic radiography are separate, study contents in information technology are only offered for diagnostic radiography students (University of Portsmouth and Queen Margaret University College). It appears that more topics are included in Japanese radiography curricula (Osaka and Nagoya Universities) (e.g., Programming in C). Recently in Japan, an attempt has been made to establish a special qualification system in medical image management by The Japanese Society of Medical

Image Management (JSMIN). No study content regarding computer aided diagnosis (CAD) was found in any of the curricula.

Digital image processing

Digital image processing is also a relatively new subject area in radiography curricula. In Europe, technical applications of digital image processing methods in different digital imaging modalities are commonly taught. Students also learn how changes in parameters affect image quality outcomes in digital imaging. Study contents in digital image processing are formulated so that students will familiarize themselves with the digital environment in hospitals and be able to understand the process of digital image formation/reconstruction and image enhancement techniques. In Japan, mathematical approaches (e.g. Fourier transform, convolution, Wiener Spectrum and MTF) are used for better understanding of digital image processing and image enhancement techniques.

Film processing

There are less study topics in conventional film radiography and film processing in Europe than before. This is a natural process in radiography education development as conventional film radiography is being rapidly replaced by digital radiography. It is highly likely that study hours which used to be spent on film processing have been shifted to other new study areas (e.g. information technology and digital image processing). Similarly as in Europe, most radiology departments in Japan are moving to digital radiography. However, since film processing is still included in the subject areas of the national examination (there is one question regarding film processing in the 2006 examination), basic study contents in film processing remain in the curricula. At Nagoya University, a lot of study content in film processing is still being taught.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This section summarises the main conclusions of the study and suggests areas of future research.

5.2 CONCLUSIONS FROM THE STUDY

The main conclusions of the study were:

1. In Europe, a wide variety of radiography education and curricular structures are still present notwithstanding the efforts of HENRE members to 'tune' such differences. On the other hand in Japan, radiography education structures and curricula appear to be much more uniform owing to the centralised guidelines from MEXT and the nationally determined subject areas of the national examination from the MLHW.

2. It is interesting to notice that radiography institutes in Europe and Japan have different approaches to the formulation of effective radiography education systems and curricula. Generally in Europe, clinical practice and clinical diagnostic principles constitute a larger portion of the curriculum than in Japan, whilst in the latter, theoretical lectures and the technological aspects of imaging (physics and medical engineering) are more emphasised.

5.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Recommendations for future research arising from the study are:

1. The inventory of themes arising from this study could be the basis of a future quantitative comparative survey which would include a bigger sample of universities.
2. The reasons for the more technological approach to radiography education in Japan as opposed to the more clinical - reporting approach in Europe should be investigated further. The specific reasons for this difference in study contents between European and Japanese curricular could be many: high esteem towards advanced technological competence within Japanese society, higher esteem for diagnostic reporting in Europe, or simply economic drivers or the presence of an undersupply / oversupply of radiologists / medical physicists.

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APPENDIX A

Objectives of HENRE Phase 1 and 2

HENRE 1

Subgroup 1: European dimension in radiography education – initial radiography training

- Explore and identify the nature of radiographic education across Europe within and outwith the HE sector
- Identify the learning outcomes of radiographic programmes of study at Bachelor level
- Develop a peer review system for radiography education with the production of a directory
- Facilitate interaction and integration for the Eastern and Central European region
- Review quality assurance mechanisms and benchmarks for radiographic education and to disseminate such information
- Develop academic and professional profiles

HENRE 2

Subgroup 1: Tuning Radiography Programmes

- Building on the work of HENRE Subgroup 1 and if appropriate the other subgroups
- Developing a summary of the radiography profession, including descriptions of degree profiles, learning outcomes, competencies, level descriptors, workload and ECTS on current Tuning methodologies

Subgroup 2: Development of learning and teaching methods used in radiographic education including e-learning, active learning and Context /Problem Based Learning (C/PBL) opportunities

- Explore the learning and teaching methods so as to develop best practice
- Explore the extent to which e-Learning opportunities are used within radiography education, including if applicable the chosen virtual learning environment (VLE)
- Develop an informative website on Active Learning and Context /Problem Based Learning (C/PBL) in radiographic education
- Develop a collaborative e-learning project

Subgroup 2: Research, Teaching and Learning

- Building on the work of HENRE Subgroup 2 and if appropriate the other subgroups
- Increase knowledge and support for research within the profession and developing a synergy between research and teaching
- Linking with other TNs and EU supported programmes

Subgroup 3: Continuing professional development

- Develop a forum for the exploration of the work practices of radiographers
- Identify the continuing professional development (CPD) requirements of radiographers
- Explore the reasons for staff shortages and the way in which the educational provision can address the issue

Subgroup 3: Life Long Learning

- Building on the work of HENRE Subgroup 3 and if appropriate the other subgroups
- The development of modules, courses and life long leaning practices within the profession

Subgroup 4: Science and Society

- Support and further develop radiation protection through the rising of public awareness and the development of education and training programmes fit for purpose

APPENDIX B

Example modular curriculum by the European Society of therapeutic Radiology and Oncology (Updated European core curriculum for radiotherapists (radiation oncologists). Recommended curriculum for the specialist training of medical practitioners in radiotherapy (radiation oncology) within Europe, 2004)

Biology of cancer

Terminology and techniques of molecular biology
Hereditary cancer
Cancer genetics
Proliferation, cell cycle and cell death in cancer
Signal transduction
Genome maintenance mechanisms for preventing cancer
The microenvironment of the tumor–host interface
Novel forms of treatment: immuno-, gene therapy, molecular targeting etc

Radiobiology

Interaction of radiation on molecular level
DNA damage
Cellular effects, mechanisms of cell death
Repair of radiation damage
Cell survival curves
Normal tissue systems
Solid tumor and leukemia systems
Effects of oxygen, sensitizers and protectors
Time-dose-fractionation, LET, radiation modalities
Acute and late normal tissue reactions
Tumor responses

Cytotoxic therapy and radiation
Predictive assays

Basic radiation physics

Atomic and nuclear structure
Radioactive decay
Properties of particle and electromagnetic radiation
Radioisotopes

Radiation physics applied in radiation therapy (RT)

X-ray tube
Linear accelerators
Specialized collimating systems
Cobalt units
Brachytherapy systems
Cyclotron
Microtron
Absorbed dose distributions
Target volume specification
Target absorbed dose specification in external RT
Target absorbed dose specification in brachytherapy
Algorithms for 2D dose calculations
3D planning, virtual and CT-simulation
Algorithms for 3D dose calculations
Principles, technical aspects and applications of conformal RT and IMRT
Special techniques (IORT, stereotactic RT)

Radioprotection

General philosophy, ALARA
Stochastic and deterministic effects

Risk of induction of secondary tumours
Radiation weighting factor
Equivalent dose-tissue weighting factor
Dose limits for occupational and public exposure
European legislation
What is evidence based in radioprotection
Imaging and target volume
Imaging modalities, procedures and technology
Disease oriented imaging
Image handling in radiotherapy
Target volume determination in clinical practice
GTV, CTV, PTV and relevant ICRU recommendations
Developments in imaging

APPENDIX C

The inventory for biomedical physics curricula for diagnostic radiography (Caruana & Plasek, 2005)

Level	Level description
L1	Competences necessary and sufficient for an appreciation of the diagnostic and monitoring capabilities of a medical imaging device, an awareness of risks to patient, self, colleagues and others from use of the device and for the effective and safe utilisation of the device with best-objects or in simulated studies using anthropomorphic phantoms in a skills-lab context. Cognitive processes are mainly at knowledge retrieval and comprehension levels.
L2	Competences necessary and sufficient for supervised effective and safe use of a medical imaging device with patients, under written protocol, scope-of-practice restricted to studies that are basic, routine and predictable. Cognitive processes are mainly at knowledge retrieval and comprehension levels.
L3	Competences necessary and sufficient for minimally supervised effective and safe use of a medical imaging device with patients, under written protocol, scope widened to include studies that are complex or somewhat non-predictable. Supervised research using the device at a basic level. Cognitive processes are mainly at the analytic and knowledge-utilisation levels.
L4	Competences necessary and sufficient for a fully autonomous effective, safe and economic use of a medical imaging device at the forefront of professional practice, comprehensive scope-of-practice in a wide variety of clinical contexts including studies that are complex and unusual, contingency preparedness, device management, allocation of resources, development of existing protocols and audits of practice, all totally guided by a test-evidence and ethical approach. Basic technology assessment and implementation of research studies in relation to new clinical applications of the device. Cognitive processes are mainly at the metacognitive and self-system thinking levels.

L5 Competences necessary and sufficient for a complete utilisation of the scientific knowledge base underpinning the effective, safe and economical use of a medical imaging device in the clinical and research contexts including clinical service development, comprehensive technology assessment and the conceptualisation, design and implementation of new device applications and user protocols, cognitive processes are mainly at the metacognitive and self-system thinking levels.

Element-of-competence

Level 1

- Define and explain the physical property/properties of tissue, which the device measures and images, including any variables impacting the value of these properties.
- List and explain target imaging outcomes (in terms of image quality criteria relevant to diagnostic or monitoring effectiveness.
- List and explain the target safety outcomes (in terms of safety criteria in relation to patient, user, colleagues and others) anticipated when using the device with respect to physical health hazards.
- List and operationally define suitable imaging device performance indicators appropriate for uses of the device and their relation to target image quality or safety criteria.
- Describe and explain the general structure and functioning of the device including user controls and settings for both image acquisition and reconstruction.
- Explain device design variables which impact device performance indicators (and hence image quality or safety criteria) at a level appropriate for users.
- Explain limitations and artefacts of the device and their impact on performance indicators at a level appropriate for users.
- Explain the physical principles underpinning the use of protective barriers, accessories and apparel.
- List and explain the protocol design variables (including appropriate device settings, use of protective barriers, accessories and apparel) which impact performance indicators (and hence image quality or safety criteria) at a level appropriate for users.
- Demonstrate ability to apply commonly used image processing and post-processing procedures for image enhancement.
- Explain user options for at least one commercially available device.
- Discuss qualitatively risk-benefit issues.
- Compare at a basic level the device with devices used in other modalities in terms of effectiveness and safety.

Level 2

- Demonstrates performance of L1 competences at a level that would ensure understanding of and strict adherence to protocols.
- List and explains the physical basis of any contradictions in the use of the device.

- Demonstrates knowledge of EU and national legislation, recommendations and regulations regarding the use of the device.
- Demonstrates understanding of the physical principles underpinning the effective and safe use of any ancillary medical devices.
- Demonstrates safe disposal of non-reusable ancillary medical devices.
- Demonstrates awareness that an imaging device should be checked before use (daily quality control), cared for during use and left in a condition for subsequent use by self or others.
- Describes the impact on performance indicators arising from device malfunction, inappropriate protocol and device misuse including any artefacts arising from these within their scope-of-practice and local procedures for reporting such malfunctions.
- Demonstrates ability to measure or calculate recommended indicators of risk and compare to established diagnostic reference levels.

Level 3

- Demonstrates performance of L1 and L2 competences at a level that would require minimum supervision when using the medical imaging device with patients, scope-of-practice widened to include studies that are complex or somewhat non-predictable.
- Explain the physical mechanism of tissue contrast enhancement by contrast media.
- Demonstrates skill in basic routine preventive maintenance and more advanced quality control appropriate for users.
- Demonstrates understanding of and ability to follow written contingency procedures.

Level 4

- Demonstrates L1-3 competences at a level expected of a user at the forefront of professional practice.
- Ability to formulate procurement plans of performance indicators and associated specifications required by the clinical needs.
- Demonstrates advanced skills in preventive maintenance and quality control of the device appropriate for users.
- Ability to identify and correct causes of below target image quality and safety criteria.
- Demonstrates physics knowledge utilisation in adjusting protocols to the needs of particular clients in studies which are complex, unusual, beyond-protocol and non-predictable.
- Demonstrates ability to conduct risk assessment and develop contingency procedures.
- Demonstrates the physics knowledge utilisation necessary to carry out advanced application of the device.
- Demonstrates the physics knowledge utilisation necessary to manage image archiving and communication systems.
- Ability to liaise with biomedical physicists in the development of imaging services (device and dose management, image quality improvement, clinical audits).
- Demonstrates the physics knowledge utilisation and the scientific attitude necessary for full effective, safe and economical use of the device in the coordination and implementation of clinical and research programmes.

Level 5

- Demonstrates understanding of the underpinning physical (including the supporting mathematical) knowledge necessary to envisage new clinical and research applications for the device and be able to liaise fully with biomedical physics – engineering professionals in the development of these applications.
- Ability to recognise ethical and economic issues regarding the device in research and service development initiatives.
- Ability to recognise technical and ethical deficiencies in documentation and legislation regarding medical devices.
- Apply physics knowledge to the technical aspects of a healthcare technology assessment report for the device.

APPENDIX D

Variable	Data	Comments / Themes
Country	Norway	
City	Tromso	
Name of university	Tromso College	
Type of university	University of Applied Sciences	
Programme	BSc Radiography	
Academic title awarded	BSc	
Duration	3 years	
Registration	Is programme approved for registration in country? Yes: x No:	
Diagnostic / therapeutic	Diagnostic radiography only Therapeutic radiography only Diagnostic and therapeutic radiography offered as separated programmes Diagnostic and therapeutic radiography offered as combined programme: x	
No. of credits for graduation	180	
Curriculum philosophy and orientation	• Prepare the students to gain knowledge and skills and develop attitude that assure the work competence in relation to the society's demands to radiographic services • Stimulate the students to responsible and reflected work within image diagnostics, image diagnostic work and radiation treatment • Make research- and development work which is related to subject, education and practise in radiography • Be national and international professionally updated and future-oriented • Cooperate with the practical field, multi-professional programs and professional areas • Encourage the students ability to cooperate with other professional groups	
Programme structure	**1st year (Meeting the profession):** Module 1 – Introduction to the profession (15 ECTS).	The programme is divided into 6 modules. Each module has specific objectives. For example in Module 5 (oncology and

<table>
<tr>
<td></td>
<td>Module 2 – Basic knowledge (30ECTS).

Module 3 – Radiation biology, thorax and skeletal radiography (15ECTS).

2nd year (Nursing and technology):

Module 4 – General imaging and nursing (60ECTS).

3rd year (Subject development and major assignment:

Module 5 – Oncology and radiotherapy treatment (15ECTS).

Module 6 – Radiographer's roles and major assignment (45 ECTS).</td>
<td>radiation therapy), a wide range of therapeutic radiography physics study contents are covered during this particular period</td>
</tr>
<tr>
<td>Curriculum content (subjects)</td>
<td>
<table>
<tr><th>Category</th><th>Subjects</th><th>Year / Module</th><th>No. of credits</th></tr>
<tr><td rowspan="5">Human biology</td><td>Study of illness and microbiology</td><td>1 / 1</td><td>1</td></tr>
<tr><td>Anatomy and physiology</td><td>1 / 1</td><td>15</td></tr>
<tr><td>The study of illness</td><td>1 / 3</td><td>2</td></tr>
<tr><td>The study of illness and microbiology</td><td>2 / 4</td><td>8</td></tr>
<tr><td>The study of illness and microbiology</td><td>3 / 5</td><td>1</td></tr>
<tr><td rowspan="6">Biomedical physics / engineering</td><td>Information and communication technology and data processing</td><td>1 / 1</td><td>1</td></tr>
<tr><td>Basic radiation physics</td><td>1 / 2</td><td>6</td></tr>
<tr><td>Applied physics for image diagnosis and treatment, apparatus</td><td>1 / 2</td><td>6</td></tr>
<tr><td>Analogue and digital image</td><td>1 / 2</td><td>1</td></tr>
<tr><td>Quality assurance and documentation</td><td>1 / 2</td><td>1</td></tr>
<tr><td>Radiation biology and radiation protection</td><td>1 / 3</td><td>4</td></tr>
</table>
</td>
<td></td>
</tr>
</table>

		Analogue and digital images	1 / 3	3	
		Applied physics of image diagnostics and treatment, study of apparatus	2 / 4	10	
		Analogue and digital images	2 / 4	4	
		Information and Communication Technology and data processing	2 / 4	1	
		Radiation biology and radiation protection	3 / 5	2	
		Applied physics for image diagnosis and treatment, apparatus	3 / 5	3	
		Quality assurance and documentation	3 / 5	1	
		Applied physics of image diagnostics and treatment, study of apparatus	3 / 6	5	
		Information technology and data processing	3 / 6	2	
		Analog and digital pictures	3 / 6	4	
	Imaging / therapeutic protocol design and training	Method principles and techniques	1 / 3	5	
		Pharmacology and the study of contrast media	2 / 4	6	
		Method principles and techniques	3 / 5	4	
	Clinical Practice	Practical placement – observing the profession	1	3	
		Practical placement – meeting the profession	1	1.5	
		General radiography	2	12	
		Practice in clinical departments	2	12	

		Subject development and in-depth assignment	3	25.5	
		Practice in radiotherapy department	3	6	
	Supportive Subjects	The interdisciplinary course	1 / 1	10	
		Psychological and pedagogical topics	1 / 1	2	
		Professional ethics and principles	1 / 1	1	
		The interdisciplinary course	2 / 4	10	
		Psychological and pedagogical topics	2 / 4	2	
		Caring and nursing of the patient	2 / 4	15	
		Methodical principals and techniques	2 / 4	4	
		Psychological and pedagogical topics	3 / 5	1	
		Caring and nursing of the patient	3 / 5	3	
		The interdisciplinary course	3 / 6	10	
		Psychological and pedagogical topics	3 / 6	4	
		Professional ethics and principles	3 / 6	5	
		Methodical principals and techniques	3 / 6	8	
		Quality development and documentation	3 / 6	7	

Imaging modalities studied	XRI	CT	MRI	RNI	US	Fluoroscopy	Mammography	Others	
	x	x	x	x	x	x	x		

Therapeutic modalities studied	No information regarding therapeutic modalities is found in the curriculum.	

Teaching methodology	Lectures	Tutorials	Seminars / workshops	Practicals / labs	e-learning	PBL	
	x	x	x	x	x	x	
Methods of assessment	Written/oral examinations, written examination at home in groups and assignment.						
Summary of physics study contents							
Physics Content	**Topics**						**Comments / Themes**
Basic physics	**Module 2** • Atomic and nuclear physics, particle and wave physics, radioactivity, ionised and non-ionised radiation, interaction between rays and tissue and radiation dosimetry. • Formation of X-ray.						
Device structure and functioning	**Module 2** • X-ray tubes and X-rays. • Registration system. • Apparatus: Overview of types of modality and their areas of use. • Use of different types of equipment and modality. • Thorax stand and exposure techniques. • Digital units. **Module 3** • X-ray apparatus: Transportable-, mammographic-, Computer Tomography-, x-ray apparatus for instance DSI. Sonograpic apparatus. • Different physical processes. • Nuclear medical physics and apparatus. • Quality control and quality assurance. **Module 5** • Radiation therapy physics: energies, dose distribution in biological tissue, dosing, wedges, filters • Apparatus for external and internal radiation.						Basic physical principles of x-ray devices as well as advanced imaging modalities in both diagnostic and therapeutic radiography are seen in the curriculum. This is one of the advantages in "combined type" programmes and the same trend is seen in other parts of the curriculum (e.g. Safety including radiation protection and Quality control).

	Module 6 • Principals, physics and the apparatus structure and function attached to MRI and Digital Subtraction Angiography (DSA). • Quality control and quality assurance attached to actual apparatus.	
Safety including radiation protection	**Module 3** • Basics principles for protection of radiation. • Acute injury and post injury by radiation. • Theoretical calculation and practical measurement of ray doses. • Marginal limits. **Module 5** • Effect of radiation on normal and cancer tissue, previous injures, post injures and tolerance. • Radiation sensitivity, radiation biology effect, radiation injures.	
Quality control	**Module 2** • Professional quality assurance and documentation. • Quality assurance, control routines and protection. • Picture quality criteria. **Module 5** • Documentation at a radiation therapy department. • Quality assurance, routines for control and radiation protection.	

Information Technology	**Module 1** • The construction and function of the computer. • Software and computer systems in the health sector. • The use of ICT for processing patient data. • Introduction to network technology. **Module 4** • Network technology. • The health sector's computer system. • Communication between two or more computer transfer systems (DICOM). **Module 6** • Tele radiology. • Computer systems in the health sector. • Legislation/protection of privacy/ data safety	
Digital image processing	**Module 2** • The creation of images, technical principles of photo, the digital images, photo plate systems, technical challenges in images production in relation to different categories of patients **Module 3** • Technical principles of photo, the digital image, the photo plate system and the technical challenges in the image production.	Rich study contents in Digital image processing as most of radiology departments in Norway have been digitalised and for this reason no study content in Film processing is found.

	• Formation of the conventional and the digital image. **Module 4** • Elements of image quality attached to apparatus and image treatment. • Image disk scanner and software for instance ADC. • Follow-up digital image and parameters, which has an impact on image disk elements, attached to the apparatus for this module. • Matrices, analogue/digital signals, dynamic area. • LUT, transfer function of the modulation, window width/level, image treatment, 3D pictures. Compression and saving. **Module 6** • Finishing process of the dilate picture and parameters that has influence on images attached to apparatus in this module.	
Film processing	Content not found.	

APPENDIX E

Variable	Data		Comments / Themes
Country	The Netherlands		
City	Eindhoven		
Name of university	Fontys hogescholen		
Type of university	University of applied sciences		
Programme	Medical imaging and radiation therapy		
Academic title awarded	BSc		
Duration	4 years		
Registration	Is programme approved for registration in country?	Yes x No	
Type of course	Diagnostic radiography only		In Holland as in most of continental Europe programmes are combined diagnostic-therapy programmes. This has the advantage that graduates have wider employment opportunities on graduation. On the downside it may mean a lower level of competence in diagnosis or therapy.
	Therapeutic radiography only		
	Diagnostic and therapeutic radiography offered as separated programmes		
	Diagnostic and therapeutic radiography offered as combined programme	x	
No. of credits for graduation	240 ECTS		40 hours of study per week is equal to 1 credit point, and 168 credit points are necessary for graduation. 168 credit points in the Dutch education system is equivalent to 240 ECTS. This means that 1 ECTS =

<table>
<tr><td></td><td colspan="4"></td><td>28 hours.</td></tr>
<tr><td>Curriculum philosophy and orientation</td><td colspan="4">Curricula at Fontys as in most of the Dutch higher educational system are competence based and problem based.</td><td>Curricula are very practice oriented as opposed to theory oriented.</td></tr>
<tr><td>Programme structure</td><td colspan="4">The education at school consists of both theoretical and practical components. The programme is divided into 2 periods: Propedeuse (1 year) and Post-propedeuse (2-4 years). Students master the relevant theory and practise necessary skills at school. One or more internships or periods of supervised work-study or practical training ('stage') are an integrated part of the post-propedeuse. These trainings, though monitored by the school, take place outside the school, in one or more relevant institutions or companies in the future field(s) of work. A research project or final thesis usually marks the end of the post-propedeuse.</td><td></td></tr>
<tr><td rowspan="14">Curriculum content (subjects)</td><td>Category</td><td>Subjects</td><td>Year</td><td>No. of credits</td><td rowspan="14">(*) SBU (studiebelastingsuren = study load hours) is used in Fontys hogescholen instead of ECTS.

Use the formula number of ECTS = number of hours divided by 28.

Lot of practical training in skills labs before hospital based training.

Big emphasis on radiation protection.</td></tr>
<tr><td rowspan="3">Human biology</td><td>Basic anatomy</td><td>Propedeuse</td><td>200</td></tr>
<tr><td>Anatomy and physiology</td><td>Post-propedeuse</td><td>60</td></tr>
<tr><td>Pathology and oncology</td><td>Post-propedeuse</td><td>140</td></tr>
<tr><td rowspan="10">Biomedical physics / engineering</td><td>Physics</td><td>Propedeuse</td><td>200</td></tr>
<tr><td>Radiation protection</td><td>Propedeuse</td><td>100</td></tr>
<tr><td>Radiation therapy: Radiobiology</td><td>Post-propedeuse</td><td>50</td></tr>
<tr><td>Diagnostic radiography: devices</td><td>Post-propedeuse</td><td>70</td></tr>
<tr><td>Radiation therapy: devices</td><td>Post-propedeuse</td><td>50</td></tr>
<tr><td>Ultrasound: devices</td><td>Post-propedeuse</td><td>50</td></tr>
<tr><td>Ultrasound: Physics of ultrasound</td><td>Post-propedeuse</td><td>30</td></tr>
<tr><td>Nuclear medicine: devices</td><td>Post-propedeuse</td><td>50</td></tr>
<tr><td>Quality assurance</td><td>Post-propedeuse</td><td>80</td></tr>
</table>

		Radiation protection: electromagnetic radiation	Post-propedeuse	40	
		Radiation protection: dosimetry	Post-propedeuse	40	
		Radiation protection: radioactivity	Post-propedeuse	40	
		Radiation protection: radiobiology	Post-propedeuse	40	
		Radiation protection: performing special computations	Post-propedeuse	40	
	Imaging / therapeutic protocol design and training	Introduction to diagnostic radiography	Propedeuse	140	
		Introduction to radiation therapy	Propedeuse	120	
		Introduction to ultrasound	Propedeuse	80	
		Introduction to nuclear medicine	Propedeuse	80	
		Patient care	Propedeuse	50	
		Diagnostic radiography: Procedures	Post-propedeuse	50	
		Diagnostic radiography: Positions	Post-propedeuse	50	
		Diagnostic radiography: Imaging	Post-propedeuse	100	
		Radiation therapy: procedures	Post-propedeuse	30	
		Radiation therapy: Treatment planning	Post-propedeuse	50	
		Ultrasound: Procedures	Post-propedeuse	30	
		Ultrasound: Imaging	Post-propedeuse	40	
		Nuclear medicine: Procedures	Post-propedeuse	30	
		Nuclear medicine: Imaging	Post-propedeuse	50	
		Department of radiology / ultrasound	Post-propedeuse	880	

		Department of radiotherapy	Post-propedeuse	520	
		Department of nuclear medicine	Post-propedeuse	400	
	Clinical practice	Practical training in skill lab	Propedeuse	400	
		Practical training in skill lab: Practical training in skill lab	Post-propedeuse	140	
		Practical training in hospital	Propedeuse	80	
		Radiation therapy: Practical training in skills lab	Post-propedeuse	140	
		Ultrasound: Practical training in skills lab	Post-propedeuse	140	
		Nuclear medicine: Practical training in skills lab	Post-propedeuse	140	
		Radiation protection: practical training in skills lab	Post-propedeuse	20	
	Supportive subjects	General introduction	Propedeuse	80	
		Social skills: Practical	Propedeuse	100	
		Social studies	Propedeuse	50	
		Nuclear medicine: Radiopharmacology	Post-propedeuse	50	
		Social studies	Post-propedeuse	200	
		Statistics	Post-propedeuse	120	
		Free choice modules	Post-propedeuse	120	
		Healthcare instruction and education	Post-propedeuse	40	
		Quality management	Post-propedeuse	40	
		Methodology	Post-propedeuse	40	
		Student supervision	Post-propedeuse	40	
		Final projects/thesis	Post-propedeuse	800	

Imaging modalities studied	XRI	CT	MRI	RNI	US	Fluoroscopy	Mammography	Others	
	x	x	x	x	x	x	x		

<table>
<tr><td>Therapeutic modalities studied</td><td colspan="6">No information regarding therapeutic modalities is found in the curriculum.</td><td></td></tr>
<tr><td rowspan="2">Teaching methodology</td><td>Lectures</td><td>Tutorials</td><td>Seminars / workshops</td><td>Practicals / labs</td><td>e-learning</td><td>PBL</td><td rowspan="2"></td></tr>
<tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Methods of assessment</td><td colspan="6">The preliminary examination at the end of the first year and the final examination which consist of a sequence of periodical examinations.</td><td></td></tr>
<tr><td colspan="8">Summary of physics study contents</td></tr>
<tr><td>Physics Content</td><td colspan="6">Topics</td><td>Comments / Themes</td></tr>
<tr><td>Basic physics</td><td colspan="6">Structure of matter; radiation
• Structure of matter
o Molecules
o Elements
o Atoms
• Energy quanta, photons
• Mass decrement
• Stable and unstable nuclides; chart of the nuclides

Radioactivity; decay processes
• Stability of the nucleus and the N/P ratio
• Decay processes ((α, β^-, EC, β^+, IT, radiation, IC and angular electrons)
• Decay schemes

Radioactivity calculations
• Activity: definition and units
• Decay constant, λ, half-life, $T_{1/2}$
• Decay equations
• Decay calculations

Radioactive equilibria and series
• Parent-daughter relations
o No equilibrium
o Transient equilibrium
o Secular equilibrium</td><td>Very comprehensive curriculum on basis radiation physics and radiation interaction with matter.</td></tr>
</table>

	• Natural radioactivity
	  o Primordial radionuclides; radioactive series
	  o Cosmogenic radionuclides
	• Artificial radioactivity
	  o Production
	
	Interaction of photons with matter
	• Attenuation of mono-energetic photons in matter
	  o Linear and mass attenuation coefficients
	  o Half-value-layer
	• Photon interaction processes
	  o Raleigh-scatter
	  o Photoelectric interaction, dependence with E and Z
	  o Compton interaction, dependence with E and Z
	  o Pair-production, dependence with E and Z
	  o Photodisintegration
	• Attenuation and energy-absorption
	
	Cellular radiobiology
	• effect of radiation at the cellular level; direct and indirect schade (damage)
	• LQ-model of cell survival
	• RBE
	
	Attenuation, transmission and absorption
	• Attenuation of mono-energetic and poly-energetic beams
	• Attenuation formula; meaning of transmission
	• Broad and narrow beams, build-up factor
	• Calculation of attenuation, transmission and shielding thickness via formulas and via. transmission graphs
	
	Dosimetry: quantities and units
	• Kerma; Gy
	• Exposure, C/kg
	• Absorbed dose, Gy	

	• LET and radiation weighting factor, w_R • Equivalent dose, Sv • The measurement of radiation doses; Bragg-Gray principle	

Device structure and functioning	Radiation protection; gas filled detectors
	• Recombination
	• Ionising chamber
	• Proportional counter
	• GM-tube
	• High voltage tube breakdown
	
	Detectors of radiation; solid state detectors
	• Scintillation detectors
	  o principle
	  o structure of measuring system
	• γ-spectrometry
	• Thermoluminescent detectors,TLD
	
	Qualitative and quantitative measurements of radiation
	• What quantities we need
	• What we need to measure
	• Efficiency
	• Background radiation
	• Counting statistics
		Lot on physics of radiation detectors but not on imaging devices themselves. This is a pity as the subject is very physics dependent.

Safety including radiation protection	Effect of radiation on risk • Deterministic effects • Risks in utero • Stochastic effects • Genetic effects • Epidemiological data • Risk factors according to ICRP-60	Lot of emphasis on radiation protection including advanced topics such as the ICRP-model for internal contamination and calculation of doses from internal contamination.

	• Tissue weighting factors • Effective dose External radiation and internal contamination • Radiation protection when working with sealed sources • Risks when working with unsealed sources • The ICRP-model for internal contamination • Simple calculations of doses arising from internal contamination Standards and statutory regulations • International recommendations; ICRP and EU-directives • National legislation incl. Dose limits	
Quality control	No information was found /available.	
Information Technology	No information was found /available.	
Digital image processing	No information was found /available.	
Film processing	No information was found /available.	

APPENDIX F

Variable	Data	Comments / Themes
Country	United Kingdom	
City	Portsmouth	
Name of university	University of Portsmouth	
Type of university	Comprehensive traditional university	
Programme	BSc Diagnostic and Therapeutic Radiography	
Academic title awarded	BSc (Hons)	
Duration	3 years	
Registration	Is programme approved for registration in country? Yes: x No:	
Diagnostic / therapeutic	Diagnostic radiography only: Therapeutic radiography only: Diagnostic and therapeutic radiography offered as separated programmes: x Diagnostic and therapeutic radiography offered as combined programme:	Diagnostic and therapeutic radiography programmes are completely separated.
No. of credits for graduation	Information was not found/available.	
Curriculum philosophy and orientation	Since 2001, the Centre for Radiography Education has been involved with interprofessional education. Radiography students take part in groups made up of students, for example from medicine, midwifery, nursing, occupational therapy, physiotherapy, podiatry, audiology, pharmacy and social work. This will enable students to broaden their outlook on the patient/client experience and to form friends and colleagues amongst other health and social care professions.	
Programme structure	The undergraduate course is organised on a block system that combines academic studies, including lectures, tutorials and small group discussions, with clinical experience under the supervision of qualified staff. A huge emphasis is made on developing the student's clinical skills by exposing them to a variety of different working environments and a range of equipment and technology. The degree course is based on study both at the University in Portsmouth and on a variety of clinical placements in hospitals in the South of England. Clinical experience constitutes approximately 50% of	

	the programme, and starts early after the first academic block in the first semester. Students from diagnostic and therapeutic radiography study together as well as other healthcare professionals. This is to provide a cross fertilisation of knowledge which will help students achieve a higher quality of learning as well as emerge as a more rounded and, ultimately, better qualified radiographer.					
Curriculum content (subjects)	**Category**	**Subjects**	**Year**	**No. of credits**	Course	
					Diagnostic	Therapeutic
	Human biology (Information regarding the number of credit assigned to Human biology subjects was not obtained.)	Introduction to Biological Sciences	1			
		Human Body (1) for Diagnostic Radiographers	1		x	
		Human Body (1) for Therapeutic Radiographers	1			x
		Human Body (2) for Diagnostic Radiographers	1		x	
		Human Body (2) for Therapeutic Radiographers	1			x
		Transport Systems and Immunity for Diagnostic Radiographers	1		x	
		Transport Systems and Immunity for Therapeutic Radiographers	1			x
		Reproduction and Urinary Systems for Diagnostic Radiographers	2		x	
		Reproduction and Urinary Systems for Therapeutic Radiographers	2			x
		Locomotor System and Skin	2			
		Nervous System for Diagnostic Radiographers	2		x	
		Nervous System for Therapeutic Radiographers	2			x

	Biomedical physics / engineering	Megavoltage and brachytherapy equipment	1	10		x
		Science of imaging and equipment	1	20	x	
		An Introduction to the Science of Imaging and Radiation Therapy	1	20	x	x
		Kilovoltage and imaging equipment for radiotherapy	2	10	x	
		Advanced imaging equipment	2	10	x	
	Imaging / therapeutic protocol design and training	Introduction to radiotherapy planning	1	10		x
		Radiotherapy planning	2	20		x
		Introduction to image interpretation	2	10	x	
		Imaging Special Care Groups	3			
		Advances in radiotherapy planning	3	20		x
		Current and future trends in oncology practice	3	20		x
		Current and future trends in medical imaging	3	10	x	
	Clinical practice	Diagnostic radiography workbased learning I	1	10	x	
		Therapeutic radiography workbased learning I	1	10		x
		Diagnostic radiography workbased learning II	2	30	x	
		Therapeutic radiography workbased learning II	2	30		x
		Diagnostic radiography workbased learning III	3	30	x	
		Therapeutic radiography workbased learning III	3	30		x

	Supportive subjects (Information regarding the number of credits assigned to Supportive subjects was not obtained.)	Information and Communication for Radiographers	1			
		Health and Illness	1			
		IPL 1- Collaborative Learning	1			
		Career Development in Radiography	2			
		Research Skills	2			
		Holistic Care and Supportive Cancer Care	2			
		IPL 2 – Inter-professional Team Working	2			
		Developing Professional Practice	3			
		Project	3			
		IPL 3 – Enabling Change in Practice	3			
		IPL4 – Inter-professional Problem-solving	3			

Imaging modalities studied	XRI	CT	MRI	RNI	US	Fluoroscopy	Mammography	Others	
	x	x	x	x	x	x	x		

Therapeutic modalities studied	Megavoltage/kilovoltage equipments, linear accelerators, portal imaging systems, other specialized equipments and brachytherapy equipments.	

Teaching methodology	Lectures	Tutorials	Seminars / workshops	Practicals / labs	e-learning	PBL	
	x	x	x	x	x	x	

Methods of assessment	Written examinations, assignments, lab write-up, object-structured clinical assessments, practical reports.	

Summary of physics study contents			
Physics Content	**Topics**		**Comments / Themes**
	Diagnostic	**Therapeutic**	
Basic physics	**1 year** • Graphs and their applications to radiography • Atoms, elements and molecules to include structure, energy levels, nuclides and chemical bonds • Electron band theory and its applications • Electromagnetic radiation and electromagnetism • Current, voltage, resistance and capacitance • An introduction to exposure factors • X and gamma ray attenuation • Electrical safety • Dose and exposure factors - introduction to dose measurement		Topics in basic physics are offered for both diagnostic and therapeutic students in "An introduction to the science of imaging and radiation therapy". Students from both courses study basic radiation physics during the first year.
Device structure and functioning	**1 year** • Rotating anode tube and insert design related to different applications. • Equipment design for use in a general X-ray room. • Image acquisition devices. • Scatter control devices – conventional and computed tomography (CT). • Image characteristics including sensitometry with regards to conventional and digital imaging techniques. **2 year** • Physical principles of MRI and US. • Radioactivity and the physical principles	**1 year** • Properties of megavoltage energy beams to include - x-ray, gamma, particle and brachytherapy beams and linear energy transfer. • Equipment to include structure and function of: Linear accelerators, portal imaging systems, specialised equipment - multileaf collimators, stereotactic adaptations and other machine accessory equipment. • Particle beams generation - generation of light and heavy particle beams. • Gamma ray beam equipment - structure and function. • Brachytherapy equipment - to include low,	More detailed study contents in each course. This is one of the advantages when diagnostic and therapeutic radiography are organised as separated courses. Rich study contents in device structure and functioning of radiation therapy is seen in the curriculum.

	of RNI. • Specialised tube design including dental equipment. • Advanced tube design. • Mobile X-ray equipment. • Fluoroscopy equipment. • Cardiovascular equipment. • Digital fluoroscopy. • Computed tomography equipment. • Mammography equipment. • DEXXA. • Understanding IR(ME)R and its effect on equipment design and testing.	medium and high dose afterloading equipment. • Beam direction/modification devices. • Equipment capabilities, limitations, advantages and disadvantages. **2 year** • Imaging equipment for tumour localisation – e.g. the planning simulator, fluoroscopy unit, processing equipment and any other equipment in general use for tumour localisation procedures. • Kilovoltage radiotherapy treatment equipment generating high-energy x-ray beams from 80Kvp to 500Kvp. • Equipment capabilities, limitations, advantages and disadvantages of all the above. • Properties of kilovoltage treatment energy beams to include penumbra, scatter etc • Beam direction/modification devices. • Filters and accessory equipment. •	
Safety including radiation protection	**1 year** • Radiation Protection – Ionising Radiations Regulations and associated codes of practices • Introduction to radiobiology		

	2 year • Safety issues for a variety of modalities. • Current legislation and practice in radiation protection.	**1 year** • Effects of therapeutic doses of ionising radiation to include: variations in cell sensitivity due to cell type, cell maturity, and position in cell cycle. Oxygen enhancement ratio, therapeutic ratio, repairable damage, cell survival curves.	
Quality control	**1 year** • Image quality evaluation: subjective and objective methods of assessing and measuring the quality of conventional film and digital image display media. • Quality assurance equipment/tests.	**1 and 2 year** • Quality assurance issues to include acceptance and constancy checks, calibrations, user maintenance and safety issues.	
Information Technology	**1 year** • Digital communication	No study content.	Study contents in information technology, digital image processing and film processing are only offered for diagnostic radiography students, and a similar approach is made at Queen Margaret university College, UK.
Digital image processing	**1 year** • Digital image readout, storage, display and manipulation.	No study content.	

	2 year • Uses of digital image manipulation and its effect on image quality		
Film processing	**1 year** • Image visualisation and manipulation: conventional film processing and hard copy display.	No study content.	Only a few copics in the concentional radiography and film processing is taught. This may be a natural process in the recent radiography educaiton develoment since the conventional radiography has been rapidly replaced by digital radiography and other modern modalities in practice. This may also indicate that the study time spent on the conventional radiography has been shifted to IT and digital image processing educaiton.

APPENDIX G

Variable	Data	Comments / Themes
Country	United Kingdom	
City	Edinburgh	
Name of university	Queen Margaret University College	
Type of university	Comprehensive traditional university	
Programme	Bsc Radiography	
Academic title awarded	BSc (Hons)	
Duration	4 years	
Registration	Is programme approved for registration in country? Yes: x No:	
Type of course	Diagnostic radiography only: Therapeutic radiography only: Diagnostic and therapeutic radiography offered as separated programmes: x Diagnostic and therapeutic radiography offered as combined programme:	
No. of credits for graduation	480 undergraduate credit points	
Curriculum philosophy and orientation	Educational aims of the programme is to develop graduate radiographers who: 1 are skilled, creative and innovative, displaying an ethos of enquiry and capable of responding effectively and sensitively to the needs and demands of individual patients and of the health care sector; 2 deal with complex issues and make informed judgments in situations in the absence of complete or consistent clinical information; 3 demonstrate leadership and or initiative and make an identifiable contribution to change and development of practices and procedures; 4 routinely apply critical reflection to inform clinical decisions, and influence own and others' roles and responsibilities;	

	5 demonstrate an independent attitude towards continuing education, with commitment to the pursuit of professional excellence in diagnostic radiography.	
Programme structure	Year One of the course has been designed as a foundation to introduce students to the concepts of healthcare and science-based technologies. The content is mostly academic- based and provides an introduction to clinical practice. Years Two, Three and Four develop this theme and integrate clinical practice with academic theory. Year Four builds on the student's skills and attributes enabling independent learning and culminating in a clinical research project. The students will be expected to take increasing responsibility for their own learning as you progress through the four years of the course. Queen Margaret University College has implemented an inter-professional education (IPE) focus within all its undergraduate healthcare courses. The IPE will help the student develop their: • mutual understanding of roles, expertise and values of other team members; • skills and strategies in working in teams and • problem solving, team decision making skills and role flexibility and ability to learn from others.	Although diagnostics and therapeutic are separated programmes at Queen Margaret University College, both courses have a similar programme structure and some study contents are shared. Diagnostic and therapeutic radiography students obtain about 42% of credit points (200 credit points out of 480) from lectures offered for both programmes (See the next section).

Curriculum content (subjects)	Category	Subjects	Year	No. of credits	Course	
					Diagnostic	Therapeutic
	Human biology	Introduction to the human body	1	10	x	x
	Biomedical physics / engineering	Science and technology	1	10	x	x
		Imaging processes	1	10	x	x
		Radiographic physics and equipments	2	10	x	
		Radiotherapy physics and equipment	2	10		x
	Imaging / therapeutic protocol design and training	Diagnostic practice 3	3	30	x	
		Radiotherapy practice 3	3	30		x
	Clinical practice	Diagnostic practice 1	1	30	x	

		Radiotherapy practice 1	1	30		x
		Diagnostic practice 2	2	40	x	
		Radiotherapy practice 2	2	40		x
		Clinical practice in diagnostic imaging 2	2	60	x	
		Clinical practice in radiotherapy 2	2	60		x
		Clinical practice in diagnostic imaging 3	3	60	x	
		Clinical practice in radiotherapy 3	3	60		x
		Clinical practice in diagnostic imaging 4	4	50	x	
		Clinical practice in radiotherapy 4	4	50		x
	Supportive subjects	Communication studies	1	20	x	x
		Psychological aspects of illness	1	10	x	x
		Professional practice	1	10	x	x
		Inter-professional education (Level 1)	1	20	x	x
		Research principles (Level 2)	2	10	x	x
		Inter-professional education (Level 3)	3	10	x	x
		Research principles (Level 3)	3	20	x	x
		Communication skills for professional practice	4	10	x	x
		Inter-professional education (Level 3)	4	20	x	x
		Research project	4	40	x	x

Imaging modalities studied	XRI	CT	MRI	RNI	US	Fluoroscopy	Mammography	Others	
	x	x	x	x	x	x	x		
Therapeutic modalities studied	Megavoltage/kilovoltage x-ray equipments, simulator and accessory equipments								

Teaching methodology	Lectures	Tutorials	Seminars / workshops	Practicals / labs	e-learning	PBL	
	x	x	x	x	x	x	
Methods of assessment	Objective structured pattern recognition and interpretation examination, written coursework, written exams, seen exams, verbal presentations, poster presentations, case studies, literature review, clinical assessments.						

Summary of physics study contents			
Physics Content	**Topics**		**Comments / Themes**
	Diagnostic	Therapeutic	
Basic physics	**1 year** • Physical principles in the are of x-radiation, including the x-ray tube, thermionic emission and production of radiation. • Radiation science to include electromagnetic radiation, intensity and quality of x-radiation and variables affecting these parameters. • Other topics in radiation science to be covered also include x-ray interaction and matter, and radiation terminology. • Photographic principles. • The radiographic image. • Perception. • Presentation and viewing of radiographers.		Although diagnostic and therapeutic are separated programmes, the same lectures (“*Science and technology*” and “*Imaging Processes*” which deal with basic radiation physics) are given to all students during the first year.
	1 year • X-ray tube, thermionic emission and production of radiation. • Electromagnetic radiation, intensity and quality of x-ray, and parameters which affect x-ray production and its quality and intensity. • Radiation interaction with matter. • Terminology in radiography.	**2 year** • Application of radiation interaction processes. • Radiation dosimetry. • Imaging in radiotherapy. • Treatment planning.	

<table>
<tr><td></td><td>• Photographic principles.
• Radiographic image.
• Recording system.
• Presentation and viewing of radiographs.</td><td></td><td></td></tr>
<tr><td rowspan="2">Device structure and functioning</td><td colspan="2">1 year
• The recording system.</td><td rowspan="2"></td></tr>
<tr><td>2 year
• Basic electrical circuitry for radio-diagnostic equipment.
• The x-ray tube design, construction, rating and use.
• Control of scattered radiation and practical considerations of beam attenuation.
• Specialized radio-diagnostic equipment, including image intensifiers, dental, mobile, mammography, computed and digital radiography equipments.
3 year
• Physics and principles of operation and image recording applications in CT, MRI, RNI, US and interventional radiography.</td><td>2 year
• Megavoltage equipment for production of photon and electron beams.
• Kilovoltage x-ray equipment.
• Simulator.
• Accessory equipment.</td></tr>
</table>

Safety including radiation protection	**1 year** • The current Statutory legislation, Ionising Radiation Regulation 1999 and Ionising Radiation (Medical exposures) Regulations 2000.		
	2 year • Statutory legislation, Ionising Radiation Regulation 1999 and Ionising Radiation (Medical exposures) Regulations 2000. • Radiation dose limitation to patients and staff and environmental monitoring. • Sealed and unsealed sources of radiation. **3 year** • Physics and principles of potential hazards and patient safety consideration. • Design and planning of a diagnostic imaging department.	**2 year** • Radiation protection regulations.	
Quality control	**3 year** • Quality assurance of equipment.	**3 year** • Quality issues.	

Information Technology	**3 year** • Computerized radiology management system. • PACS.	No study content found.	Study contents in information technology, digital image processing and film processing are only offered for diagnostic radiography students, and a similar approach is made at University of Portsmouth, UK
Digital image processing	**1 year** • Basic concepts of digital imaging processes.		
	3 year • Advanced imaging processes to include: digital imaging, digital subtraction, computerized radiology, management systems and PACS.		
Film processing	**1 year** • Radiographic film processing, to include automatic systems.		Only a few copics in the concentional radiography and film processing is taught. This may be a natural process in the recent radiography educaiton develoment since the conventional radiography has been rapidly replaced by digital radiography and other modern modalities in practice. This may also

		indicate that the study time spent on the conventional radiography has been shifted to IT and digital image processing education.

APPENDIX H

Variable	Data					Comments / Themes
Country	Japan					
City	Nagoya					
Name of university	Nagoya University					
Type of university	Comprehensive traditional university					
Programme	BHSc Radiography					The course belongs to School of Health sciences, Faculty of Medicine, Nagoya University.
Academic title awarded	BHSc					BHSc = Bachelor in Health Science
Duration	4 years					
Registration	Is programme approved for registration in country?	Yes	x	No		Graduates must pass the national radiographer's examination for a radiographer's qualification.
Type of course	Diagnostic radiography only					
	Therapeutic radiography only					
	Diagnostic and therapeutic radiography offered as separated programmes					
	Diagnostic and therapeutic radiography offered as combined programme				x	
No. of credits for graduation	124 Japanese credits (14 credits must be obtained from optional units).					1 lecturing credit = 15 to 30 hours 1 practice credit = 30 to 45 hours.
Curriculum philosophy and orientation	This course aims to educate future radiographers, educators and researchers who will be able to cope with rapidly increasing radiographer's roles and developments in modern radiography. The objective of this course is to train future radiographers who:					

	1. Have specialized knowledge in radiography and appropriate decision making techniques in clinical situations. 2. Have a good knowledge of other health care occupations and can work as a part of a medical team. 3. Have a good knowledge necessary for researches and developments in future radiography. 4. Have a good knowledge necessary for radiography education. 5. Can contribute their knowledge and skills in international radiography societies.	
Programme structure	The 1st and 2nd years involve basic general education such as foreign languages, communication, philosophy, literature, art and scientific subjects (mathematics, physics, biology and chemistry). The 3rd year emphasizes specialized radiography education (Radiographic imaging techniques, radiation measurement, medical engineering/physics and radiation therapy etc) and the final year is mainly assigned to clinical trainings and finial projects.	

	Category	Subjects	Year	No. of credits	
Curriculum content (limited to content directly related to radiography only i.e., not including languages etc)	Human biology	Anatomy I B	1	2	Basic general subjects offered during the 1st and 2nd year are not listed (25 credits) here since they are not directly related to radiography education.
		Biochemistry A	1	1	
		Anatomy II B	1	2	
		Pathology A	2	1	
		Anatomy III B	2	1	
		Microbiology A (Optional)	2	1	
		Immunology (Optional)	2	1	
		Thoracic and abdominal anatomy	3	1	
	Biomedical physics / engineering	Medical information analysis and practice	1	1	
		Basic Electric/electronics Engineering and Practice	1	1	
		Information Technology and Practice	1	1	
		Medical Electric Engineering	1	2	
		Radiation chemistry and practice	2	2	
		Medical Electronics and Control Engineering	2	2	

		Medical Imaging Engineering	2	2	
		Medical Physics I	2	2	
		Radiographic Image Formation	2	2	
		Radiation Hygiene (Optional)	2	1	
		Medical Instrument Engineering I	2	2	
		Medical Electric/Electronics Engineering Practice	2	2	
		Medical Physics II	2	2	
		Radiation Safety Control	2	2	
		Radiographic Image Formation Experiment	2	1	
		Medical Imaging Engineering Practice (Optional)	2	1	
		Computer Programming and Practice (Optional)	2	1	
		Radiation chemistry experiment	3	1	
		Radiobiology	3	1	
		Laws and regulations related to radiation	3	1	
		Radiation measurement II: Experiment	3	1	
		Medical Instrument Engineering II	3	1	
		Medical Instrument Engineering III	3	1	
		MRI	3	1	
		Radiation Measurement I	3	1	
		Radiation Measurement II	3	1	
		Radiation Measurement III	3	1	

		Medical Imaging Engineering Experiment	3	1	
		Nuclear Medicine I	3	2	
		Medical Physics III (Optional)	3	1	
		Medical Information System engineering (Optional)	3	1	
		Medical Instrument Engineering Experiment	3	2	
		Medical Informatics	3	1	
		Ultrasound	3	1	
		Medical Instrument Engineering I Practice	3	1	
		Radiation Safety Control Experiment	3	1	
		Bio-material Engineering (Optional)	3	1	
		Radiation safety Control Practice (Optional)	3	1	
		Image processing in nuclear medicine (Optional)	4	1	
		Quality assurance in radiotherapy (Optional)	4	1	
		Medical Instrument Engineering Experiment	4	2	
		Radiation Measurement III Practice	4	1	
		Medical Image Processing Practice (Optional)	4	1	
		Environmental Radiation Management (Optional)	4	1	
		Radiotherapy Simulation System (Optional)	4	1	
	Imaging / therapeutic protocol design and training	Radiographic image interpretation and practice I	3	1	

		Radiographic image interpretation and practice II	3	1	
		Contrast imaging	3	1	
		Radiology	3	1	
		Emergency radiography	3	1	
		Radiographic techniques and practice I	3	1	
		Nuclear medicine II	3	1	
		Radiotherapy I	3	2	
		Radiotherapy II	3	1	
		Radiographic techniques and practice II	3	1	
		Interventional radiology (Optional)	3	1	
		Data analysis of radiographic examinations (Optional)	4	1	
		Computer aided analysis (Optional)	4	1	
	Clinical Practice	Radiographic techniques practice A	4	2	
		Radiographic techniques practice B	4	2	
		Radiographic techniques practice C	4	2	
		Nuclear medicine practice A	4	2	
		Nuclear medicine practice B	4	1	
		Radiotherapy practice A	4	2	
		Radiotherapy practice B	4	1	
	Supportive subjects	Introduction to Health Care Sciences	1	1	
		Environmental hygiene	1	2	
		Psychology (Optional)	2	1	
		Social welfare (Optional)	2	1	
		General nursing (Optional)	2	1	

		Introduction to medical economics (Optional)	2	1	
		Pharmacology (Optional)	2	1	
		Radiological science seminar	3	1	
		International team work in healthcare (Optional)	3	1	
		Radiopharmacology (Optional)	4	1	
		Final Project	4	3	

Imaging modalities studied	XRI	CT	MRI	RNI	US	Fluoroscopy	Mammography	Others	Others: PET, SEPCT and Gamma knife.
	x	x	x	x	x	x	x	x	

Therapeutic modalities studied	Brachytherapy, total body irradiation, intraoperative radiotherapy, particle beam radiation therapy, 3-D conformal external beam radiotherapy, linear accelerators, microtron, microselectron, simulators, stereostatic radiosurgery, radiotherapeutic CT scanners and thermotoron.	

Teaching methodology	Lectures	Tutorials	Seminars / workshops	Practicals / labs	e-learning	PBL	PBL is not yet a common teaching method in Japan. Passive education is still a preferred teaching method in most of the academic situation. PBL has been introduced to medicine and nursing but its long-term outcome is still unknown.
	x	x	x	x			

Methods of assessment	Written examinations, assignments and lab reports. Graduates are allowed to sit for the national examination for radiographers and must pass the examination in order for them to be qualified.	

Summary of physics study contents

Physics Content	Topics	Comments / Themes
	Electric/electronics/medical engineering **1 year** • *Direct current circuits and electrical circuits.* • *Alternate current circuits and electrical circuits.* • *RLC capacitors and transformers.*	Note: Study contents offered from optional units are shown in italics. Electric/electronics/medical engineering occupies a large part of the

	• *Solid states.* **2 year** • Electron energy in solid matters and characteristics of semiconductors. • Diodes (schottky barrier and pn junctions) and transistors (bipolar and Field effect transistor). • Solid state devices (thyristor, Thermoelectric element, optoelectronics element, hall sensor, piezoelectric element). • Laser diodes and superconductivity. • Transistor signals and electronic amplifiers. • Operational amplifiers and feedback. • Frequency characteristic of operational amplifiers. • Pulse circuits (derivative, integration, wave shaping, multi-vibrator • Logic gates, logical connective and Boolean algebra. • Logic gates and The Karnaugh map. • Analog-to-digital converters. • Instruments and control system, devices, circuits and electric motors as control elements. • Feedback and power supply. • Varieties of electronic devices and applications. • Electric charge and electrostatics. • Direct current circuits and magnetic field. • Alternating current (AC) and electrical circuits. • Three-phase (electric power). • Electric appliance. • Electromagnetic instrumentation. • Building a multimeter (multitester), functional experiment and calibration. • Measurement methods using an oscilloscope. • Measurement of space charge effect of diodes. • Measurement using a bridge circuit and calibration of meters using a potentiometer. • Characteristics of solid state devices. • Characteristics of multi-vibrator and wave shaping. • Logic gate. • Operational amplifier circuits. • AD DA converters. • Electronics in radiation measurement.	programme. Theoretical lectures on engineering and physics are followed by experiments (often measurements of radiation and instruments).

	• *Visual evaluation.* • *Howlett chart.* • *CD (contrast detail) diagram.* • *Image evaluation by SNR.* • *DQE and NEQ.* • *Information theory – SDT (signal detection theory).* • *ROC analysis.* • *Digitalisaiton of images (sampling and quantization).* • *Nyquist–Shannon sampling theorem and aliasing error.* • *Digital image characteristics.* • *TV – image signals, camera tube and scan converter.* • *TV – mechanisms of colour TV and high definition television (HDTV).* **3 year** • Characteristic curve measurement of screen-film system – distance method, bootstrap method, time scale sensitmetric method, chart method and slit method. • Measurement of the modulation transfer function (MTF) of the focal spot. • Wiener spectrum measurement of screen-film system. • MTF measurement in CR – edge method. • Wiener spectrum measurement CR. • Measurement of the focal spot. • Evaluation of collimator, half value layeror and effective energy. • Timer accuracy test. • Tube voltage/current calibration and x-ray wave observation. • Characteristics of condenser x-ray generators and measurement of effective exposure time. • Practice with a human phantom and constructing protocols. • Grid test. • Handling of radiation protective clothes and measurement of lead equivalent. • Inverter x-ray high voltage generators: knock sensor and flat-response sensor. • *Concepts of bio-material engineering, types of bio-materials, sterilisation of bio-materials and biocompatibility of biomaterials.* • *Compositions and characteristics of tissue equivalent bio-materials (bone, muscle and soft*	

	tissues). • *Different types of biomaterials and biomaterials used in radiography such as catheters.* • *Performance evaluations of phantoms used in CT and quality control.* • *Compositions and characteristics of breast tissue equivalent biomaterial and basic principles in mammography.* • *Performance evaluations of phantoms used in ultrasound quality control.* • *Bone densitometer quality control.* **Basic radiographic physics** **2 year** • Definition of images and light. • Height diameter curves. • WS Curves. • Measurements of image formation parameters. • Sensitivity. • Focal spot blur. • Compton effects. • Motion blur. • Definition and different types of radiation • Special relativity • General/basic quantum theory • Structure of an atom • Structure of the nucleus of an atom • Concepts and characteristics of computed radiography. • Introduction to radiation physics, generating radiation, responsibilities of diagnostic medical radiographers. • X-ray attenuation, half-value layeror and effective energy (Eeff), x-ray spectrum, and x-ray image formation. • Diagnostic x-ray system unit, x-ray system for different diagnostic purposes. • Mechanisms of the x-ray tube. • Characteristics of the x-ray tube. • Characteristics of the x-ray tube focal spot, permissible load and heat capacity.	

	• Radiation distribution and leakage radiation. • Collimator, photoelectric emulsion layer, intensifying screen, cassette and grid. • Basic concepts of medical x-ray high voltage generator: single 2 peaks x-ray high voltage. • Basic concepts of medical x-ray high voltage generator: triple 6 peaks x-ray high voltage generators. • Basic concepts of medical x-ray high voltage generator: triple 12 peaks x-ray high voltage generators. Constant high voltage x-ray generators. • Conventional x-ray devices and fluoroscopy • Radioisotopes. • Radioactive equibrium. • Nuclear reaction, nuclear fission, and nuclear fusion. • Amount and unit of radiation. • Interaction of photons and matters. • Interaction of charged particles and matters. • Interaction of neutrons and matters. • Radiation production system. • Magnetism. **3 year** • Physics for radiation measurement. • Unit of radiation and related terms. • Types of radiation detectors. • Measurement of the primary and attenuation radiation. • Calibration of instruments and phantoms. • Dose and energy measurements of x-ray and cathode ray. • Depth dose distribution ratio equivalent field. • Introduction to MRI: mathematics for electromagnetism • Basic principles of electromagnetism • Principles of nuclear magnetic resonance • Spin echo • Reconstruction of MR images (frequency and phase encodings) • Introduction: the role of RNI in medical situations • Basic radiation physics in RNI.	

	• Radiation measurement in RNI: radiation and its interaction between matters. • Measurement techniques in RIN. • Basic ultrasound: Mathematical explanation of waves. • Latest technology in US: harmonic imaging contrast agents of ultrasound, three dimensional imaging and elastography. • *Wave-particle duality.* • *Schrödinger equation.* • *Examples of Schrödinger equation.* • *Simple harmonic oscillators.* • *Physical quantity and operators.* • *6-7. Energy bands.* **4 year** • Characteristics of an image intensifier. • Measurement of the x-ray spectrum. • Adjustments of tomographic devices. • *Process of radiotherapy simulation.* • *Necessary hardware for radiotherapy simulation.* • *Measurement of high energy photon/beams in radiotherapy.* • *Radiation dose calculation algorithm.* • *Monte Calro method.*	
Device structure and functioning	**3 year** • Basic of NRI, historical background and an outline of gamma camera. • Gamma camera (structure of a gamma detector, scintillator and collimator). • PET – Structure of the detector and image reconstruction algorithm.	

	• SC (scatter correction) in SPECT. • AC (attenuation correction) in SPECT. • Basic PET-CT. • Performance indicators of RNI devices. • Basic concepts of high energy gamma ray, x-ray, cathode ray and particle beam. • Particle accelerator: Cockcroft-Walton, van der Graaff, cyclotron, synchrotron, betratron and cobal-60 radiation therapy unit. • Basic concept of linear accelerators and acceleration. Traveling wave phototubes and standing wave phototubes. • Linear accelerators: electron guns, acceleration tubes, microwave generators (magnetron and klystron). • Linear accelerators: Emitting/generating x-ray and cathode ray and multi-leaf collimator (conformal radiotherapy/ conformationirradiation). • Microtron, basic radiotherapy simulation system, and related accessories (block cutter, wedge filter, compensation filter and bolus). • Stereotactic radiosurgery (gamma knife, linac radiosurgery and cyber knife). • Simulators, radiotherapeutic CT scanners, microselectron, RALS (remote after loading system). • Thermotron (hyperthermia). • Mechanisms of MR devices. • Basic devices in RNI. • Ultrasound device structures. • Fluoroscopy and angiography devices. • Image intensifier, x-ray TV camera, camera tube and CCD. • X-ray TV and x-ray image devices. • DSA and digital radiography systems. • CR, DR, FPD and digital x-ray systems. • CT system and image reconstruction methods. • Multi-slice CT. • Mammographic devices.	
Safety including radiation protection	**2 year** • Basic information and applications of radiation and radioactive isotopes.	

	• Safe handling of sealed radioactive isotopes and radiation production system. • Safe handling of unsealed radioactive isotopes. • Radioactive waste disposal. • Design and management of radiation facilities. • Law (laws concerning the prevention from radiation hazards due to radioisotope and others) • Physics, chemistry and biology related to radiation safety control. • Measurement techniques for radiation management. • Radiation hazards and management in individuals. • Radiation safety control in medicine (clinical situations). • *Effects of radiation on human bodies.* • *Safe handling of x-ray devices and isotopes.* • *Laws and regulations.* • *Prevention of radiation hazard (isotope).* • *Amount and unit of radiation* • *Radiation irradiation.* **3 year** • *Measurement of ambient dose.* • *Measurement of radioisotope in the air.* • *Measurement of radioisotope in water drain.* • *Measurement of patient radiation dose.* • *Sealing of radiation.* • *Removal of radioisotope contamination.* **4 year** • Making Mix DP phantoms • Measurement of PPD (percentage depth dose) and output coefficient using an ionisation chamber and a water phantom. • Thimble/shallow ionizing chambers and measurement of TMR (triple modular redundancy) using a water equivalent phantom. • TLD and radiation dose.	

	• Plotting radiation dose distribution using an isodose plotter. • Calculation of radiation dose distribution using a radiotherapy simulation system. • *Radiation in natural environment.* • *Concepts of radioactive dating.* • *Trend of environmental radiation.*	
Quality control	**3 year** • Quality assurance of monitor diagnosis. • Quality assurance of mammography. • Measuring instruments and radiation measurement. • X-ray energy measurement. • Radiation measurement in CT. • Performance evaluations of CT. • Quality assurance of MRI. • Principles and units of radiation dose, radiation measurement theory, measuring instruments, data analysis, measurement of radioactivity and energy in RNI. • Measurement of x-ray TV resolution. **4 year** • Quality control of x-ray devices using an x-ray output analyzer. • Specification tests for bone mineral densitometers. • Specification tests for mammographic devices.	
Information Technology	**1 year** • Basic computing. • Components of a computer. • Data format and usage – volume of data and data compression. • Computer development and technology.	IT education starts from basic IT related topics such as computing, programming languages and computer net-works. It then continues to cover advanced medical

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Programming languages and operation systems
Computer network – mechanisms and advantages.
Computer viruses and computer security.
Operation of computers and e-mail.
Use of basic application softwares.
Medical information and database research using world-wide-web.
Making a home-page – use of tags on HTML, uploading web-server and pictures and links.

2 year

Basic programming.
Basic numerical calculation.
Input/output and display of digital images.
Inversion and tone reproduction.
Filtering in the space domain (convolution/spatial filtering).
Filtering in the frequency domain (Fourier transform).
Threshold of images.
Erosion and dilatation of binary format images.
Labeling
Feature extraction.
Mass detection in mammographic images.

3 year

Basic self-information.
Artificial intelligence of "system", and "digital/analog quantities".
Basic computing.
Net-work.
Medical information system.
Concepts of Evidence Based Medicine.
PACS, DICOM and image network system.

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<td>informatics such as PACS and DICOM.</td>
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Digital image processing	**2 year** • Image processing - Fourier transform. • Image formation – Convulsion. • MTF (modulation transfer function). **3 year** • Image construction theory and artifacts in US. • CT system and image reconstruction methods. • CT image reconstruction practice. • Spiral CT and image reconstruction. • *Digital image processing techniques in DSA, CT, MRI, US and CR.* **4 year** • *Basic image processing and image processing systems.* • *Forms of image processing algorithm.* • *Histogram processing and binary format image processing.* • *Neighborhood processing, distance transformation and skeletonization.* • *Image conversion and enhancement, and edge detection.* • *Line detection – Hough transform.* • *Smoothing and noise reduction, moving average model and median filter.* • *Laplacian kernel and image sharpening.* • *Image reconstruction and inverse filter.* • *Inverse filter and wiener filter.* • *Image compression and predictive coding.* • *Run-length coding.* • *JPEG algorithm.*	Mathematical approcahes are employed to teach digital image formation/reconstruction, image enhancement methods and evaluation of image quality outcomes.
Film processing	**2 year**	Alhotugh radiography in

	• Characteristics of an intensifying screen – film combination. • Concepts and characteristics of photography. • Crystal structure of silver chloride and mechanism of light detection. • Mechanisms and types of film processing. • Structures, characteristics and handling of silver chloride. • Characteristics of light and radiation. • Penetration characteristics of x- and γ - rays. • Relationship between emulsion, intensifying screen and film. • Chemistry of film processing. • Effects of processing on a film image. • Chemistry of developing and fixation. • Characteristic curve and x-ray sensitometry. • Evaluation of image quality parameters. • Dark room light experiment. • Experiment of changes in film image characteristics at different processing time and temperatures. • Measurement of chemical fixation. • Duplication of x-ray films. • Experiment of micro-photography and printing.	Japan has been widely digitalised, topics conserning film-radiography are still offered.

APPENDIX I

Variable	Data		Comments / Themes
Country	Japan		
City	Osaka		
Name of university	Osaka University		
Type of university	Comprehensive traditional university		
Programme	BHSc Radiography		The course belongs to School of Allied Sciences, Faculty of Medicine, Osaka University. This course was the first radiography course (3 year programme) established in 1968) in Japanese national universities. This course was also the first radiography course that was upgraded to a 4 year programme in Japan.
Academic title awarded	BHSs		BHSc = Bachelor in Health Science
Duration	4 year		
Registration	Is programme approved for registration in country?	Yes: x / No:	Graduates must pass the national radiographer's examination for a radiographer's qualification.
Type of course	Diagnostic radiography only		
	Therapeutic radiography only		
	Diagnostic and therapeutic radiography offered as separated programmes		
	Diagnostic and therapeutic radiography offered as combined programme	x	

No. of credits for graduation		
Curriculum philosophy and orientation	The programme focuses on medical engineering and physics (*) which are necessary for the development of modern diagnostic imaging modalities, as well as the core components of radiography such as effective use and safety management of ionizing radiation.	(*) the latest statistics shows that half of graduates are employed by companies such as TOSHIBA medical systems and Philips Japan or continue their study in post-graduate courses. A lot of emphasize is made on electric/electrics/medical engineering and physics rather than common radiography education typically seen in most of other radiography institutes. 76.3% of all the candidates passed the national examination for radiographers (58^{th}, 2006), while 65.3% of students from Osaka University passed the same examination. This may indicate that the curriculum is heavily based on physics and engineering as stated above.

Programme structure	The students spend the first period (1.5 years) on "general subjects" (e.g., cultures, environment, science, human/computer languages, health and sports) and "basic specialized subjects" (e.g., mathematics, physics, chemistry, biology and statistics). This is a preparation period for students before they start radiography education. Radiography education starts from the second semester of the second year, although a few subjects related to radiography and healthcare may be done during the first period of the course. This educational structure aims to help radiography students have a basic knowledge of health science necessary during the second period of the programme and also encourage them to interact with other students from different faculties of the university.				
Curriculum content (limited to content directly related to radiography only i.e., not including languages etc)	**Category**	**Subjects**	**Year**	**No. of credits**	The majority of subjects offered during the first year of the programme are not directly related to radiography and these subjects are not listed.
	Human biology	Biochemistry	2	2	
		Physiology	2	2	
		Biomedical experiments	2	1	
		Biomedical molecular engineering (Optional)	2	1	
		Imaging anatomy	2	2	
		Imaging anatomy practice	2	1	
	Biomedical physics / engineering	Introduction to medical physics	1	2	
		Radiation biology	2	2	
		Medical electronics engineering I	2	2	
		Electric engineering	2	2	
		Electric engineering practice	2	1	
		Radiation biology	2	2	
		Radiation physics	2	2	
		Radiation safety control	2	2	
		Radiographic image practice	2	1	
		Radiographic imaging theory	2	2	
		Medical informatics I	2	1	
		Medical informatics II	2	1	
		Medical electronics engineering practice	3	1	
		Image information science training	3	1	

		Radiochemistry practice	3	1	
		Biomedical optics (Optional)	3	1	
		Image formation science	3	2	
		Medical instrument engineering I	3	2	
		Medical instrument engineering II	3	2	
		Medical instrument engineering practice I	3	1	
		Medical instrument engineering II practice	3	1	
		Nuclear magnetic resonance	3	2	
		Radiation measurement	3	2	
		Radiation measurement practice	3	1	
		Radiochemistry practice	3	1	
	Imaging / therapeutic protocol design and training	Introduction to radiology	2	2	
		Imaging techniques	3	1	
		Radiation oncology I	3	2	
		Radiation oncology II	3	2	
		Cardiovascular technology	3	1	
		Medical Imaging I	3	2	
		Medical imaging II	3	2	
	Clinical practice	Clinical training I	3	5	
		Clinical training II	3	5	
		Special clinical training	4	2	
	Supportive subjects	Introduction to allied health sciences	1	2	
		Clinical pharmacology	2	2	
		Medical sociology	2	1	
		Nursing	2	1	
		Emergency medicine	4	1	

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<tr><td></td><td colspan="5"></td><td colspan="2">Thesis work</td><td>4</td><td>6</td><td></td></tr>
<tr><td rowspan="2">Imaging modalities studied</td><td>XRI</td><td>CT</td><td>MRI</td><td>RNI</td><td>US</td><td>Fluoroscopy</td><td>Mammography</td><td colspan="2">Others</td><td rowspan="2"></td></tr>
<tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td colspan="2"></td></tr>
<tr><td>Therapeutic modalities studied</td><td colspan="9">No information regarding therapeutic modalities is found in the curriculum.</td><td></td></tr>
<tr><td rowspan="2">Teaching methodology</td><td colspan="2">Lectures</td><td colspan="2">Tutorials</td><td colspan="2">Seminars / workshops</td><td>Practicals / labs</td><td>e-learning</td><td>PBL</td><td rowspan="2"></td></tr>
<tr><td colspan="2">x</td><td colspan="2">x</td><td colspan="2">x</td><td>x</td><td></td><td></td></tr>
<tr><td>Methods of assessment</td><td colspan="9">Written examinations, assignments and lab reports. Graduates are allowed to sit for the national examination for radiographers and must pass the examination in order for them to be qualified.</td><td></td></tr>
<tr><td colspan="11">Summary of physics study contents</td></tr>
<tr><td>Physics Content</td><td colspan="9">Topics</td><td>Comments / Themes</td></tr>
<tr><td>Basic physics</td><td colspan="9">Electric/electrics/medical engineering

2 year

• Electric charges and electric fields, and calculation of direct current.
• Relationships and characteristics of magnetism, magnetic field, magnetic flux density, magnetization curve, magnetic flux and magnetic induction.
• Single phase in circuit analysis
• Calculation of transient phenomena in direct current and electron movement in electromagnetic fields.
• Induced current, and measurement of electric and electromagnetic fields.
• Multiple phase alternating current (3 phase).
• Transformers.
• Characteristics of direct-current machines.
• Characteristics of synchronous machines.
• Structures and characteristics of induction machines.
• Structures and characteristics of electric motors.
• Measurements of electrical resistance using voltmeters and ammeters.
• A discussion on the best electric circuits (which give minimum measurement bias when voltage is applied to resistance and electric current is measured using a voltmeter and a ammeter).
• Test for shunts, multipliers and measurement errors of voltmeters and ammeters -</td><td>Although it is an optional unit, applications of laser in medicine taught in biomedical Optics is a unique and new approach in radiography education.

Study contents in engineering may be experiment based. Theoretical lectures are followed by practices and experiments. For example, Medical instrument engineering I and II are followed by Medical instrument engineering practice I and II irrespectively.

Physiology is taught from</td></tr>
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	Understandings of voltmeters and ammeters which are used to increase the measuring ranges of moving-coil type instruments, and testing for errors produced by voltmeters and ammeters. • Measurement of electric resistance using Wheatstone's bridge - Understanding of the basic principles of Wheatstone's bridge and how to measure electric resistance. • How to use an oscilloscope - Basic principles, structures and characteristics of an oscilloscope and how to use it. • Vector locus of RC. • The basics of electric circuits. • Important aspects of electric circuits (direct electric circuits etc). • Introduction to semiconductor fabrication (electrical conductivity and the energy band model). • Introduction to solid state physics (impurity diffusion and the Fermi level). • PN junctions and diodes. • Basic transistor theory. • FET (field effect transistors) and IC (Integrated circuits). • Characteristics of amplifiers. • Transistors of amplifier circuits. • Feedback and arithmetic circuits. • Basic analog circuits (differential and integrate circuits). • Pulse circuits. • Logic gates. **2 year** • *Biomedical optics and basic characteristics of light waves I (plane wave, polarisation, refraction and reflection).* • *Basic characteristics of light waves II (interference, coherence, diffraction and laser focusing using a lens).* • *Basics of medical laser (concepts, types and structures of laser, laser deposition, interactions of laser and human bodies and medical applications of laser).* • *Biomedical optical measurement/diagnosis I (percutaneous measurements and fiber optic measurements).* • *Biomedical optical measurement/diagnosis II (theory and applications of laser CT, (optical) luminescence spectroscopy in ophthalmology and optical measurements in medical technology).*	a physics perspective.

	3 year • Operational characteristics of diodes. • Operational characteristics of rectifier circuits. • Static characteristics of transistors of emitter follower circuits. • Basic characteristics of CR and pulse circuits. • Operation amplifiers and arithmetic circuits. • CR turning circuits. • Voltage test and x-ray spectra: measurements of tube voltages and x-ray spectra while altering tube voltages and amperes, also measurements of x-ray spectra and attenuation using aluminum. • NMR and relaxation time - Measurements of relaxation time. • Measurements of specific charge of the electron - Observation of electrons when they are accelerated to circular motion in magnetic fields, measurement of specific charge of the electron and comparison with betatrons. • Measurements of characteristics of laser - measurements of the patterns of light diffractions and polarisation, using a laser diode. **Basic physics** **1 year** • Medicine and physics: Common ground between medicine and physics and study areas related to medical physics. • Physical phenomena and human bodies: Physical phenomena, sensory system against physical volume and their effects in the human body. • Physical phenomena and medicine: Physical methods for diagnosis and treatment, and artificial biomaterial. • Physical properties of the human body: General Positive and passive properties, human body compositions, characteristics of human physical properties, properties of electricity, units and properties of electricity in matters, properties of electricity and the human body structure, equivalent electric circuits, high frequency waves, properties of heat generation, migration and diffusion of heat, changes in the human body tissue when heat is applied. Body temperature and physiological functions, properties of light, different types and wave length of light, light reflection, absorption and scatter of the skin, suntan, sunscreen and skin types, mechanical	

	properties of the human body elasticity, viscosity, biotribology and acoustic properties. • Physical phenomena in the human body: Diffusion and transfer of substances, intracellular and extracellular fluids, passive and active transports, transport of macromolecules and particles, and osmotic pressure, membrane and action potential, electrically excitable tissues, electrocardiogram, brain waves and electromyogram, units in magnetism, magnetic fields emitted from the human body, biomagnetic measurements and its applications, body temperature, body temperature measurements and changes in body temperature, voice, heart sound and respiratory sound. • Sensory physiology: Types, categories, strength and adaptability of sensations and conversion of physical and chemical stimulations. Visual, acoustic, balance, taste and olfactory sensations. **2 year** • Introduction to radiation. • Types of radiation, energy, radiation field and charged particles. Understanding of "ionization, excitation, fluence, stopping power and flight distance". • Generation of radiation (Bremsstrahlung and characteristic x-ray), generation efficiency and reduction. Understanding of "interaction of atoms and electrons". • Interaction with matters. Understanding of "interactions between photons and matters". • Neutrons, radioactive nuclides, characteristics of the X-ray and half value layers. Understanding of "interactions with neutrons, radioactive decay and half life". • Amount, units and measurements of radiation (1). Understanding of "radiation measurement in general". • Measurement of patient radiation dose. • Interactions of particle beams and matters. • Mass energy transfer coefficients and absorption coefficients. • Radiation in healthcare. • X-ray generators. • Introduction to radiographic imaging theory: History and development of radiation image engineering. • H&D curves: Density, H&D curves and effective exposure value transfer. • X-ray tube focal spot: Structure of the focal spot, focal spot sizes and strength distribution in x-ray, focal spot sizes, image quality and its measurement. • Scatter radiation: Scatter radiation and image quality, measurement of the scatter fraction and	

	removal of scatter radiation using grids. • Importance of exposure factors, adjustments and corrections of exposure factors. • Image quality evaluation: Contrast, sharpness and noise. **3 year** • Introduction to NMR: historical background, the magnetic moment and resonance conditions. • Basic parameters of NMR: chemical shift, coupling constant and relaxation time. • Pulsed Fourier transform: explanation of magnetic field's movements using a vector model. • Basic pulse sequences: T1, T2 and spin-echo. • 2-D measurements. • Basics of MRS (magnetic resonance spectroscopy) and NMR spectra. • Medical magnet resonance (1): Biological samples and exchange systems in NMR. • Medical magnetic resonance (2): 31 NMR in living tissues (in vivo NMR). • Pulse sequences used for imaging: gradient echo • Fast imaging: multi-echo, multi-slice, EPI (echo-planar imaging) and (gradient and spin-echo).	
Device structure and functioning	**3 year** • Theories of radiation measuring devices (radiation detectors) – Functions of ionization chambers and their characteristics, excitations and chemical reactions caused by radiation, and characteristics of a radiation chamber. • Characteristics of Geiger Muller Counter and counting efficiency: resolving time, counting losses and counting efficiency • Low energy beta ray and radiation measurement. • Radiation measurement of gamma ray: structure of a cylindrical scintillator and basic knowledge of gamma ray measurement. • Measured value and statistical fluctuation. • Measurement of radiation distribution: theory of autoradiography, techniques and quantitative analysis. • Measurements of gamma ray spectra and energy - Relationship of wave height and energy and concepts of half value layer and effective energy.	Experiments regarding radiation detection are intensively done. This may indicate that different types of devices for a wide variety of experiments are available. Although diagnostic and therapeutic radiography are combined in this course, there is no study unit designated for radiotherapy devices in the curriculum.

	• Measurement of X-ray effective energy - X-ray continuous spectra and concepts of half value layer and effective energy. • Energy measurement of beta ray - Processes of beta ray attenuation and theory of energy measurements. • Measurement of exposure dose using an ionizing chamber - Measurements of exposure and absorbed doses. • Measurement of patient and occupational radiation dose - Characteristics of film badges and TLDs used for monitor patient and occupational radiation dose measurements. • Environmental radiation monitoring and measuring devices - Characteristics of radiation monitoring devices and radiation safety control. • Definition and unit of radiation measurement - Definition and units used for radiation measurements. • Measurement of low energy β ray (^{3}H ^{14}C ^{32}P) using a liquid scintillation counter. • Measurements of x-ray radiation dose and effective energy and measurement of half value layer. • Measurement of γ spectra using a multi-channel analyzer. • X-ray tubes and accessories (focal spot): production of x-rays and thermo electrons, history of x-ray tubes, structures of diagnostic x-ray tubes, characteristics of x-ray tubes, permissible load and heat capacity and related accessories (focal spot). • High voltage x-ray generator: Basic concepts of high voltage x-ray generators, inverter high voltage x-ray generators and condenser high voltage x-ray generators. • Automatic exposure control systems: Basic theories and concepts of automatic exposure control systems, sensors, characteristics, calibration and different types of applications. • Control panel: outline of control panel, functions of the main operation system, design and installation of control panels and their programmes. • Detectors: vidicon x-ray detectors, I.I, IP and CCD. • X-ray image display systems: x-ray television systems (RTVS), I.I, optics, vidicons, image display monitors and fluoroscopy TV monitors. • Diagnostic imaging modalities: I.I for circulatory examinations and orthopaedic surgeries, fluoroscopic and mammographic imaging devices. • Invention, developments and basic theory of CT scanners. • Hardware and system structure of CT: production of radiation and x-ray tubes. • Detectors and projection data collection. • Theory of MRI: nuclei and magnetic fields in nuclear magnetic resonance. • Measurement of relaxation times and processes.	Although it is an optional credit, "laser therapy" is found in the curriculum.

	• Magnetic gradient fields and Fourier transform. • Selective excitation and imaging using 2-D Fourier transform. • *Laser therapy I (devices used in laser therapy and thermal laser therapy).* • *Laser therapy II (photodynamic laser therapy, low power laser therapy and laser lithotripsy).*	
Safety including radiation protection	**3 year** • Concepts and types of laws, restrictions and protections by laws and meanings of license. • Crimes, wrongful conducts, nonfulfillment of obligations, social punishments against crimes, responsibilities and descriptions and expressions of laws. • Rights and responsibilities of healthcare professionals. • Laws and regulations related to healthcare, medicine and welfare. • Radiological technologist law and other related laws: medical radiation technologists and laws, radiology technologists law and its enforcement regulations and laws. • Radiation protection and law: objectives of radiation protection, law frameworks in Law concerning prevention of radiation hazards, ICRP recommendations and the atomic energy basic law. • Restriction of radiation dose by law: laws and regulations related to radiation doses in healthcare and (applications of different types of radiation source for individual institutes). • Law concerning prevention of radiation hazards due to isotopes etc and related laws and regulations (1): Objectives and outlines, permission and authorization of dealing, renting and disposing radioactive sources, and radiation hazards. • Law concerning prevention of radiation hazards due to isotopes etc and related laws and regulations (2): Standard design of radiology facilities, responsibilities of users, dealers and (disposers), and radiation handling supervisors. • Medical law and radiation protection is diagnostic imaging (1): Concepts of medical laws and related laws and regulations. • Medical law and radiation protection in diagnostic imaging (2): Radiation protection in diagnostic imaging. • The pharmaceutical affairs law and related laws and regulations: Objectives and definition of the pharmaceutical affairs law, types and restrictions of pharmaceuticals, radioactive	Japanese laws and regulations (also ICRP regulations) concerning healthcare, social welfare and the use of radiation safety as well as radiation protection in clinical practice are taught.

	pharmaceuticals, medical devices and imaging devices. • Laws related to Labor Safety and Sanitation: Labour standards law, Labour safety and sanitation law, National Personnel Authority Regulations and ship law. • Patients' rights and informed consent. • Objectives of radiation safety control and historical background. • The basic of radiation, radiation dose control and radiation protection in diagnostic imaging. • Basics of physiology and pathology related to radiobiology. • Adverse effects caused by radiation. • Basics of radiation carcinogenesis and radiation exposure from radioisotopes. • Radiobiology (test) • Dose measurements and management in radiation safety control	
Quality control	**2year** • Characteristic curves of radiographic films: Understanding sensitometry of radiographic films, plotting characteristic curves of each combination using bootstrap methods and comparison of their characteristics. • Star test pattern: measurement of focal spot size - Measurement of the effective focal spot size using star test pattern. • Calculation of MTF of x-ray tube focal spot sizes - Calculation of MTF from characteristic curves and density distribution of x-ray tube focal spot (sizes). • Calculation of noise in radiographic images - Measurement of noise pattern in radiographic images using RMS granularity and observation of related factors such as density and granularity during experiments. • Calculation of MTF using square wave charts - Plotting characteristics curves and square wave charts, measurement of image density distribution using a microdensitometer, strength transformation using characteristic curves, calculation of square wave MTF, coltman's conversion equation, and calculation of MTF of screen-film systems. **3 year** • Performance evaluation of CT devices.	

Information Technology	**2 year** • Introduction to medical informatics. • Hospital information system. • Medical economics. • Local medical information network. • Remote medical assistance network. • Mechanisms of computers. • Basic principles of information networks. • Computer network technology. • Information security. • Descriptions and operations of medical information. • Databases and their applications in healthcare. **3 year** • Data processing. • Data collection and literature research. • Presentation techniques. • Introduction to the C programming language. • Introduction to image processing in C.	Advanced IT topics such as a computer language C is included.
Digital image processing	**2 year** • Fourier analysis: Impulse functions, periodic (impulse) function, convolution integral, Fourier transform, Fourier series and the Nyquist-Shannon sampling theorem. • MTF: Space frequencies, transmission characteristics, effective exposure value transfer, and chart methods. • Wiener Spectrum: Impact of noise, mean value, dispersion, the autocorrelation function, measurement of wiener spectra, transmission and density (concentration) fluctuations, film noise and quantum mottle • Image quality evaluation using a space frequency analysis: Evaluation of sharpness and noise	Mathematical approcahes are employed to teach digital image formation/reconstruction, image enhancement methods and evaluation of image quality outcomes.

	using a space frequency analysis. **3 year** • Introduction and image input/output processes. • Display of digital images. • Image filtering. • Image deterioration and reconstruction. • Binary image processing • Image quality evaluation. • Recognition of dynamic images. • Image reconstruction. • Image reconstruction theory: basic mathematics. • Fourier transform and back projection. • Projection data. • Convolution back projection. • Principles of image formation in MRI: magnetic gradient fields, slice thickness, spatial encoding, image reconstruction and K-space.	
Film processing	**3 year** • Comparisons of the characteristics of x-ray films and photostimulated luminescence, and measurement of characteristic curves.	

APPENDIX J

Credit numbers necessary to qualify from programmes in Europe (HENRE Subgroup 2, 2006)

Country code Institution ID	Town/City	How many hours = I credit (ECTS)	Total number of credits (ECTS) a student has to collect each year	Total number of credits (ECTS) a student has to collect to qualify from the programme
AT2	Neustadt Wr	20	60	180
BE1	Brussels	27	60	180
DK1	Copenhagen	30	60	210
DK2	Aalberg	12	60	210
DK3	Odense	12	60	210
EE1	Tallinn	40 = 1.5	60	210
AL2	Athens	11	60	240
FI1	Oulu	40 = 1.5	60	210
FI2	Tampere	40 = 1.5	60	210
FI3	Helsinki	40	40	140
HU2	Pecs	30	60	180
IE1	Dublin	25	60	240
IS1	Rekjavik	20	60	240
IT1	Florence	10	60	180
LT1	Vilnius	40 = 1.5	60	180
MT1	Valetta	24	60	240
NL1	Fontys	27	60	240
NL2	Haarlem	28	60	240
NO1	Oslo	25	60	180
NO2	Trondheim	27	60	180
NO3	Tromso	27	60	180
SE1	Umea	No answer	60	180
SE2	Stockholm	40 = 1.5	60	180
SE3	Jonkoping	40	40	180
SE4	Orebro	40 = 1.5	60	120
SE5	Vakjo	40	40	180
SE6	Goteborg	10 = 1.5	60	120
SK1	Martin	No answer	60	180
UK2	Lancaster	10 = 0.5	120	360
UK3	Hatfield	20	60	180
UK4	Aberdeen	20	60	240
UK5	Edinburgh	10	120	480

APPENDIX K

Radiography modalities taught in EU (HENRE Subgroup 1, 2006)

Town/City	Diagnostic Imaging Equipment Operation																
	2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k	2l	2m	2n	2o	2p	2q
Innsbruck	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Neustadt Wr	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Brussels	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	D	D
Frankfurt	E	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E
Oldenburg	E	E	D	E	E	E	E	D	E	E	E	E	E	E	NR	E	E
Dresden	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Copenhagen	E	E	E	E	E	E	E	E	D	E	E	NR	E	E	E	D	D
Aalberg	E	E	E	E	E	E	E	E	NR	E	E	D	E	E	D	D	D
Odense	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	D	D
Tallinn	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Athens	E	E	D	E	E	E	E	NR	NR	E	E	E	E	E	D	E	E
Athens	E	E	D	E	E	E	E	NR	NR	E	E	E	E	E	D	E	E
Oulu	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Tampere	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Helsinki	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	E	E
Paris	D	E	E	E	E	D	D	D	NR	E	E	E	E	E	D	E	E
Franconville	E	D	E	E	E	E	D	D	NR	E	E	E	E	E	D	E	E
Semmelweis	E	E	E	E	E	E	E	E	D	E	E	D	E	E	E	D	D
Pecs	E	E	E	E	E	D	E	E	D	E	E	E	E	E	D	E	E
Dublin	E	E	E	E	E	E	E	D	D	D	D	D	D	E	NR	NR	NR
Rekjavik	E	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	E
Florence	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Vilnius	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Valetta	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D

Fontys	D	E	E	E	E	E	E	E	D	E	E	E	E	D	D	E	E
Haarlem	E	E	E	E	E	E	E	D	E	E	E	E	E	D	E	E	E
Oslo	D	E	E	E	E	E	E	NR	NR	E	E	E	E	E	NR	E	E
Trondheim	NR	E	E	E	E	E	E	D	NR	E	E	E	E	E	NR	E	E
Tromso	D	E	E	E	E	E	E	D	D	E	E	D	D	E	D	E	E
Lodz	E	D	D	E	E	D	E	E	E	E	E	D	E	E	D	E	E
Gdansk	E	E	E	E	E	E	D	E	D	E	E	E	E	NR	D	E	E
Coimbra	E	E	E	E	E	E	E	E	E	E	E	NR	E	E	E	NR	NR
Umea	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	NR	NR
Stockholm	E	E	E	E	E	E	E	E	NR	E	D	no answer	E	E	NR	NR	NR
Jonkoping	E	E	E	E	E	E	E	E	NR	E	E	E	D	E	E	NR	NR
Orebro	E	E	E	E	E	E	E	E	D	E	E	E	E	E	NR	NR	NR
Vakjo	E	E	E	E	E	E	E	E	NR	E	E	E	E	E	NR	NR	NR
Goteborg	E	E	E	E	E	E	E	E	NR	E	E	NR	E	E	NR	NR	NR
Martin	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Martin	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	E	E
Ljubjana	E	E	D	E	E	E	E	NR	E	E	E	E	E	E	NR	E	E
Ankara	E	E	E	E	E	E	E	D	E	D	D	NR	NR	D	D	D	NR
Salford	E	E	E	E	E	E	E	E	E	E	E	E	E	E	NR	NR	NR
Lancaster	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	NR	NR
Hatfield	E	E	D	E	E	E	E	D	E	E	D	E	E	E	D	NR	NR
Aberdeen	D	E	E	E	E	E	E	D	D	D	D	D	E	E	D	NR	NR
Edinburgh	E	E	E	E	E	E	E	D	E	E	D	E	E	E	D	NR	NR

2a Analogue film system
2b Digital image capture
2c digital image manipulation and archival/PACS
2d X-ray tubes
2e General and conventional equipment
2f Automatic exposure controllers
2g Fluoroscopic equipment
2h Ultrasound scanning
2i dental equipment

2j Computed tomography scanning
2k magnetic resonance scanning
2l Nuclear medicine equipment
2m Mammography equipment
2n Mobile radiographic unit
2o Bone densitometry
2p therapy simulation and treatment planning
2q Radiotherapy treatment units

E – Essential
D – Desired
NR – Not required

APPENDIX L

Definitions of the terms used in Teaching Methodology (HENRE Subgroup 2 Final Report Year 3 2004-2005)

Lecture:	Information transfer by the teacher (expert) to a large group of student listeners in an essentially non interactive environment. Focus is on introduction of new material.
Seminar:	Student led teaching and learning on a specific pre-researched topic. The emphasis on active participation and the sharing of ideas/knowledge.
Workshop:	Sharing of ideas in-group setting on a given task. Teacher facilitates active participation (brain-storming).
Clinical training:	Learning in the clinical environment. Student encouraged to transfer theory into practice under supervision.
E-Learning:	A method of interactive learning in a digital environment e.g. discussion forum, computer assisted learning, no fixed time or location, web-based environment. Can involve assessment.

APPENDIX M

Survey data: Learning and teaching methods used (HENRE Subgroup 2 Final Report Year 3 2004-2005)

	Total Responses	Mostly %age	Occasionally %age	Rarely %age	Not used %age
Lectures	49	64%	32%	0	4%
Seminars	47	28%	55%	13%	4%
Small group sessions	44	43%	43%	7%	7%
PBL	46	11%	33%	26%	30%
Independent Learning	45	27%	24%	29%	20%
e-learning	48	17%	25%	23%	35%
Clinical	48	70%	25%	0	5%
Other	6	0	100%	0	0