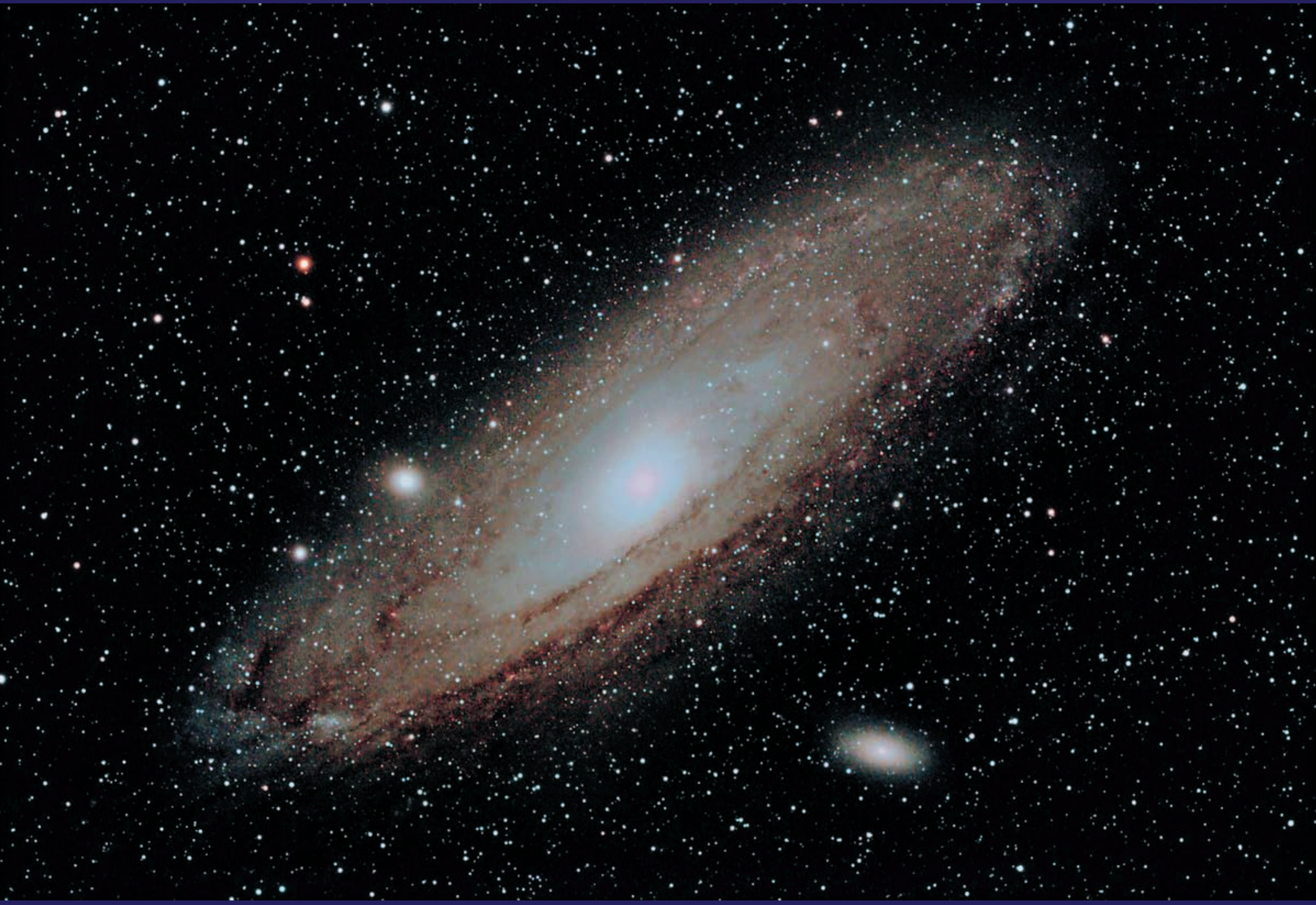
A Vision for Science Education in Malta



Consultation Document 2011

Ministry of Education, Employment and the Family

A Vision for
Science Education
in Malta

The National Curriculum Framework
2011

Consultation Document

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Hon. Dolores Cristina
Minister

Ministry of Education,
Employment and the Family

The new draft National Curriculum Framework is based on the principles of employability, lifelong learning and quality of life, aiming to equip young people with the key competences required to meet the challenges of Malta's labour market.

In Science Education, the key challenge is to find a way in which to make this field of study a valuable and rewarding experience that enables learners to take informed decisions in their ongoing interaction with their changing environment and in their quest to improve their quality of life.

This document outlines a proposed Science Strategy based on a vision of Science Education that envisages the development of decision-making and problem-solving competences and skills using an evidence-based approach. The vision also aims at building a solid knowledge and skills basis, throughout early childhood education and compulsory schooling, in order to empower learners to consider careers in Science and related areas at further and higher education levels.

I wish to extend my sincere appreciation to the stakeholders represented in the Working Group tasked with drawing up the proposals contained in this document.

I would like to invite all stakeholders to fully engage with the vision being recommended and discuss its potential impact and outcomes during the consultation process. This will be instrumental for us to be able to plan a roadmap for Science Education in Malta that is truly broad and balanced and that has an ongoing relevance in today's changing world.

Dolores Cristina

Message

Prof. Grace Grima
Director General

Directorate for Quality
and Standards in Education

The need to set up a working group on science education to analyse the current situation of science education in Malta and to suggest a way forward that adequately addresses current as well as future national needs in the area was felt soon after the working group for the updated national curriculum framework started work on its terms of reference.

The vision for science education in Malta was developed by stakeholders from the University of Malta, the Chamber of Scientists, the MATSEC Examinations Board and the three education sectors. In essence, the working group worked on the following tasks:

- a literature review of the state of science education in various countries, particularly in the EU, to identify the issues and challenges that characterise this area of study;

- a stocktaking exercise of the state of science education locally – within the various sectors, with the aim of acknowledging and learning from past initiatives, experiences and studies;

- an exploration of the various science education programmes and resources available on the market to familiarise the working group with the predominant pedagogical approaches for learning/teaching science; and

- a study of various scenarios for local science education to explore and forecast logistic and training needs, resources and time frames for the implementation of the strategy for science education.

The proposed vision was developed after careful consideration of local and international science education research, reports and documentation as well as an analysis of the local current situation of science education and future needs. It is hoped that the suggested way forward adequately addresses current as well as future national needs in this area.

With the changes envisaged, the working group hopes that science education produces distinctly better outcomes than the current results. Improvement can be assessed by using the following indicators:

- Malta will improve its performance in the TIMSS and PISA surveys in science achievement. Malta will obtain a better placing and an improved average score mark in science achievement, among the participating countries;

- a significant reduction of the percentage of the students' population that achieve at or are below the Low Benchmark of science achievement in the TIMSS survey - currently standing at 52% of the cohort; and

- an increase in the number of students who:

    - take up the science option at secondary level;

    - sit for the SEC examinations in science;

    - study one or more science subjects as part of their Matriculation Certificate; and

    - read for under-/post-graduate degrees in science and/or science related areas and carry out research projects that attract more funding from local and foreign sources.

I take this opportunity to encourage stakeholders to engage with this vision and participate actively in the consultation process from now until the end of this calendar year so that together we can map the way forward for Science Education in Malta.

Grace Grima

Executive Summary

The current document was prepared by a working group of science and science education experts set up in November 2008 by Prof Grace Grima, Director General for Quality and Standards. The brief was to analyse the current situation of science education in Malta and to suggest a way forward that adequately addresses current as well as future national needs in the area.

The State of Science Education

All across Europe, there have been mounting concerns with the type of science education that children and young people are experiencing. Locally, the present system is riddled with the effects of piecemeal strategies and decisions based on intuition rather than on empirical evidence that have accumulated throughout the years. This history of piecemeal strategies is proving to be the main obstacle restricting innovation in educational institutions and hindering the development of learner-centred pedagogies.

a) The state of Primary School Science

While children are expected to develop fundamental scientific concepts, skills and attitudes during the primary school years, studies have identified a number issues and challenges for primary science within the international sphere. These include the primary school teachers' lack of confidence in teaching science and lack of skill in using ICT to teach the subject and their inability to cater for the diversity of learners. Also highlighted is the need of high quality initial training and continuous professional development.

b) The state of Secondary School Science

Although the current trend in Europe for science education is two-fold: producing future scientists and providing the rest of citizens with a basic level of scientific literacy, historically, science education is focused mainly on the first aim. Consequently, most science curricula especially at secondary level end up being loaded with scientific knowledge, and limited time for experimentation and reflection, depriving students from understanding the process and nature of science.

The Trends in International Mathematics and Science Survey (TIMSS) in which Malta participated for the first time in 2007 with the Form 3 students, highlighted some concerns in the area of science education. Malta achieved 30th place in science achievement amongst 49 participating countries. Nearly all other participating EU countries attained a better placing than Malta. The survey showed that 52% of the Maltese students are at or below the Low Benchmark. On a positive note, 5% of Maltese students performed at the Advanced Benchmark compared to the international average of only 3%. The survey also showed that Malta enjoys a relatively young and highly qualified cohort of science teachers.

Following the review of the international and local context in science education, the working group agreed on a vision statement on science learning in Maltese schools.

Vision Statement

An educational system that provides all learners with the scientific knowledge and understanding necessary to help them function within the context of a dynamic world characterised by continuous change.

The Purposes of Science Education

Science education seeks **to develop the scientific literacy of all learners** enabling them to make informed decisions as they strive to improve their quality of life and to understand the changing contexts. Besides imparting knowledge, science education also **develops skills and ways of thinking that are important for decision-making and problem solving using an evidence-based approach**. It also needs **to provide a strong foundation for learners who wish to pursue a career in science and other science-related careers** that require them to focus on science at post-secondary and tertiary levels.

To address these purposes, our educational system has to be flexible enough to allow all learners with the potential of following a career in science or a science-related profession to do so at any point in their schooling. It also implies an inclusive educational setting that acknowledges, caters for and validates a whole range of abilities: from low to high achieving students.

Realising the Vision

This vision can be realised by providing quality science curricula. The effectiveness of these curricula is enhanced when strong links are made with the work done in the Early Years[1], between the primary and secondary education curricula and with the post-secondary science curricula. By co-ordinating the work at all levels, unnecessary repetition is avoided and age-appropriate subject content and skills can be emphasised.

In practice this means that:

- during their early years children are provided with different environments and opportunities that stimulate their curiosity; develop their observation skills; support and promote a sense of inquisitiveness; and learn how to ask questions about how and why things work and how to investigate objects and materials and their properties.

- at the primary level, all learners can follow a core science curriculum which offers flexibility so that individual schools develop their own programmes based on issues and themes that are particularly relevant to their school community.

- throughout the secondary level, science will continue to be a fundamental component of the curriculum allowing learners to explore scientific concepts through a thematic approach. All students in Forms 1 and 2 will follow the Core Science curriculum that

1 The Early Years refer to children from birth to the age of seven implying that early childhood education and care starts in the home, is experienced in non-compulsory and informal settings including child-care and kindergarten, but is extended into the first two years of compulsory primary school.

will provide a good foundation for further studies in science. In Forms 3, 4 and 5, the Core Science programme will continue to be offered to students who do not wish to specialise in science. This ensures that all learners acquire an adequate level of scientific literacy. Other students may wish to study science in more detail or aim at a career in science or a profession that requires a deeper knowledge of science. For these students, the science curriculum in Forms 3, 4 and 5 needs to offer options that allow them to choose increasing degrees of exposure to science education based on their personal interest and abilities; and follow specific directions that reflect personal preferences and/or possible future career inclinations and choices.

- a smooth transition from secondary to post-secondary level may require a study of the possible paths followed by students at post-secondary level, how the gap between curricula at the two levels can be minimised and how post-secondary education is organised.

The Secondary School Science Curriculum Structure

Realising the vision necessitates an overall rethink of what constitutes science education at the various levels of schooling. However, the major change proposed is in the way science education is organised, taught and learnt at the secondary level. At the secondary school level, the curriculum will be organised as shown in Table I and Figure I.

Table I: The science curriculum at secondary school level

Forms	Core/Option (number of lessons/week)	Student group
1 & 2	Core Science (4)	All students
3, 4 & 5	Core Science (4)	Core Science programme
	Materials Science (4) + Physical Sciences (4)	Science Option 1
	Materials Science (4) + Life Sciences (4)	Science Option 2
	Physical Sciences (4) + Life Sciences (4)	Science Option 3
	Materials Science (4) + Physical Sciences (4) + Life Sciences (4)	Science Option 4

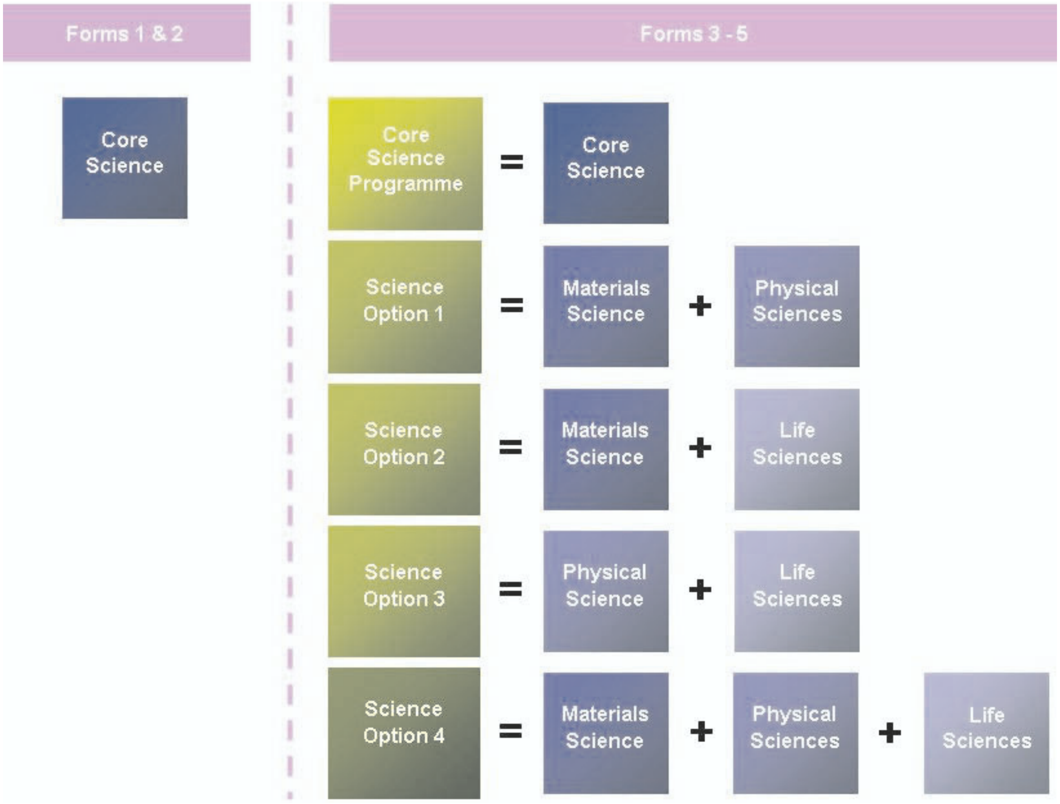

Figure I: *The various Science options on offer in the curriculum*

All students in Maltese schools are entitled to learn science in order to obtain a basic scientific literacy. The basic concepts of science will be organised around three main strands that will be dealt with in **all** the science options offered (i.e. Core Science, Materials Science, Physical Sciences and Life Sciences):

- developing scientific understanding;
- developing scientific inquiry skills; and
- being able to relate science to technology, society and the environment.

The basic core concepts of science will be dealt with through these three strands in the Core Science programme. The Materials Science, Physical Sciences and Life Sciences programmes will deal with these basic core concepts and continue to build on them in more depth.

The **Core Science** will help students attain scientific literacy by providing them with a balanced view of science covering a range of concepts, principles, theories and methods of investigation. The content will be organised in themes bringing together knowledge from different areas to show the coherence of science and the need to use concepts from different sciences to understand natural phenomena and to solve everyday problems.

The **Materials Science** curriculum will focus on a variety of natural and synthetic materials, their chemical and physical properties and uses in everyday life and natural processes. It will deal with the structure of materials, their properties and reactions. It will also focus on how different materials can be created and combined in different ways to develop new products that improve the quality of life as well as the application of materials in different fields.

The **Physical Sciences** curriculum will provide more detailed explanations and applications of the physical and chemical concepts and principles in everyday life. It will mainly deal with matter, energy and the interactions between them on the microscopic scale, and with the formation and evolution of the Earth, the Solar System and the Universe on the macroscopic scale.

The **Life Sciences** curriculum will help students to study in greater depth the biological and related chemical concepts. It will deal mainly with organisms, their structure, functions and interactions with the environment on microscopic and macroscopic scales thus presenting a systemic perspective of life on our planet.

The new vision for science that is being proposed is **not** a cosmetic change of the science subjects currently offered (Chemistry, Physics and Biology) but a paradigm shift in the way science is currently taught. It implies a methodology that promotes inquiry-based learning that requires a deeper and integrated understanding of science and how scientific knowledge is structured. In inquiry-based learning learners are actively engaged in investigations and involved in working out meanings and explanations in groups – through the social construction of knowledge. Thus learners understand not only scientific knowledge, but also what it means to do science.

A model for Teaching and Learning Science

The vision of science education outlined needs to be accompanied by a shift in the pedagogical processes used in the science classroom. It also needs to be accompanied by a shift in our vision of learning towards socio-cultural learning theories which emphasise the importance of socio-cultural experiences in influencing development. New ideas about learning suggest that students learn best when they engage with each other and learn from one another. Within this perspective, learning occurs in a 'community of practice'.

The model of instruction which best reflects these ideas about learning is inquiry based learning which involves the use of a planned sequence of instruction that places the students at the centre of their learning experiences, encouraging them to explore, construct their own understanding of scientific concepts and relate to other concepts. This model known as the 5E model allows pupils to Engage, Explore, Explain, Elaborate, and Evaluate. This process is described in the literature as follows:

"*The teacher first determines the topic of inquiry and provides a discrepant event or focus question or problem to* ***engage*** *student interest and curiosity. The students, with their teacher as guide and coinvestigator, begin to* ***explore*** *the problem or question. They make further observations and attempt to* ***explain*** *the phenomena they observe. The teacher then challenges students to* ***elaborate*** *on their understandings by linking observations to prior knowledge and by applying the concepts and skills in new situations. Finally, the teacher encourages students to* ***evaluate*** *their understandings and abilities, and the teacher evaluates or assesses the areas of strengths and weaknesses exposed by student performance in the activity*". (Jorgenson, Cleveland and Vanosdall, 2004, p.19)

Assessment

Assessment is for learning: Assessment should take place alongside learning and provides students with continuous, qualitative feedback which allows them to grow and move forward in their learning. This approach helps learners become autonomous and take responsibility for their own learning. The planned science curriculum will identify general learning outcomes for science which focus on understanding, investigating, communicating, linking and applying science. Learning outcomes can be captured and recorded through various forms such as: investigations and problem solving activities; learning logs and portfolios; self assessment; peer assessment; and formal tests and examinations.

At the end of secondary schooling students may opt to sit for their Secondary Education Certificate Examination in the following subject areas: (i) Core Science; (ii) Materials Science, (iii) Physical Sciences and (iv) Life Sciences. The results of each of these examinations will be recorded and certified as separate examination subjects. Each of the syllabi of these SEC examinations (Core, Material, Physical and Life Sciences) will satisfy the requirements to enter post-secondary education.

For students who may not be able to reach the required standard at SEC level certification of their attainment in science can be provided either internally by the school or externally or both.

Learning Outcomes

The learning outcomes for the Early Years, the Primary School level and the Secondary Schools level need be reviewed to ensure consistency with the curriculum that will be adopted. Doing science at the primary school level for children aged 5 to 10+ through to the secondary level for young students aged 11 to 16 involves:

- **Understanding** the world around us by asking questions about it, seeking ways of answering these questions, and developing knowledge that helps us to understand nature and to improve our quality of life;

- **Investigating** phenomena and processes by planning investigations, making predictions, deciding how to check predictions fairly, making observations and taking accurate and reliable measurements, analysing the evidence obtained, critically evaluating evidence, and drawing conclusions;

  Communicating scientific knowledge by means of oral, written, graphical and other appropriate means using scientific language, that is terminology, conventions and techniques appropriate to the task;

  Linking science to everyday life and **Applying** the scientific knowledge gained to explain natural phenomena and how things work, and to enjoy an improved quality of life.

The implementation of the new science curricula requires

- the production and/or selection of interesting and attractive curriculum materials. The working group inspected a number of textbooks and also met with textbook publishers about the books available. The textbooks were of a high quality, but they need to be adapted to the Maltese context and according to the themes selected for Core Science, Materials Science, Physical Sciences and Life Sciences. Apparently, these adaptations can be negotiated with the publishers who are willing to make the necessary changes and write new units if required. The cost, the timeframe and any conditions involved need to be negotiated.

- adequate laboratory facilities, ICTs, equipment, chemical and biological resources, as well as suitable software, learning guides and other curriculum materials that are relevant to the local context.

- finding ways of dividing classes for science lessons with the aim of increasing the opportunities for students to carry out hands-on activities that are essential for inquiry-based learning. It is planned that Form 1 students will start benefitting from such an arrangement as from September 2011. Phased in over two years such an arrangement will cover both Forms 1 and 2 by September 2012. Although Form 3, 4 and 5 students studying Physics, Biology and Chemistry are already being grouped in this way, the new model will further increase the number of science groups and hence the number of teachers of science that will be required. It would therefore be imperative to phase in the reform over a period of five years, starting at Form 1, so that the demand on human capacity will start to be felt in the third year and will increase gradually over a period of a further three years.

A major advantage of the reform is that it will provide the system with more teaching practice placements for undergraduates training to become science teachers. Currently the educational system is caught up in the vicious circle that while supply is not meeting demand, at the same time, schools are not in a position to offer more teaching practice placements. This new model can break us free from that constraint.

In the meantime, the country needs to extend the number of incentives to whoever opts to become a science teacher. Apart from continuing to offer a higher stipend during initial teacher education years one should actively consider introducing incentives like doubling the allowance (paid to teachers) to all newly appointed teachers of science subjects for the first years of their career.

- professional and creative timetabling skills due to the constraints that the reduction in class size and the number of science options available have imposed on the exercise. Catering for the new timetabling demands necessitates giving priority to the science options over other timetabling limitations.

- the support from education officers, college principals and heads of school, heads of departments, primary science support teachers, and laboratory technicians.

- the adequate preparation of science teachers. This entails a review and the strengthening of the initial science teacher education course and an evaluation of the current in-service courses with a view of improving the continuing professional development programmes for practising teachers.

Currently **science teachers** can be teaching Integrated Science in Forms 1 and 2, Biology, Chemistry or Physics in Forms 3, 4 and 5 or a combination of all of these. **All teachers need re-training in methods of teaching since the proposed curriculum emphasises the inquiry approach to learning.**

Re-training is also needed to enable teachers to teach certain aspects of content which they have not taught for a number of years because they were teaching a single science subject or because the content is new.

Time frame for the consultation process

Date	Task
Mar 2011	Finalisation of draft Science Strategy Document and dissemination among critical friends for feedback
Apr 2011	Publication of Science Strategy Document for consultation
May – Dec 2011	National Consultation process
Jan 2012	Finalization of Science Strategy Document

Targets

With these changes, science education should produce distinctly better outcomes than the current results. Improvement can be assessed by using the following indicators:

- Malta will improve its performance in the TIMSS and PISA surveys in science achievement. Malta will obtain a better placing and an improved average score mark in science achievement, among the participating countries;

- a significant reduction of the percentage of the students' population that achieve at or are below the Low Benchmark of science achievement in the TIMSS survey – currently standing at 52% of the cohort; and

- an increase in the number of students who:

    - take up the science option (i.e. Materials Science, Physical Sciences and Life Sciences) at secondary level;

    - sit for the SEC examinations in science;

    - study one or more science subjects as part of their Matriculation Certificate; and

    - read for under/post-graduate degrees in science and/or science related areas and carry out research projects that attract more funding from local and foreign sources.

Preamble

On the 28th November 2008, Prof Grace Grima, Director General, Directorate for Quality and Standards in Education, set up a working group of science and science education experts to analyse the current situation of science education in Malta and to suggest a way forward that adequately addresses current as well as future national needs in the area. The working group was composed of the following members:

Mr Gaetano Bugeja
Education Officer Physics
Directorate for Quality Standards in Education

Mr Raymond J Camilleri
Director
Curriculum Management & eLearning

Dr Deborah Chetcuti
Faculty of Education
University of Malta

Mr Godwin Degabriele
Science Teacher
Independent Schools Representative

Mr Mario Falzon
Education Officer Chemistry
Directorate for Quality Standards in Education

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Dr Josette Farrugia
Faculty of Education
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Prof Alex Felice
Chamber of Scientists &
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Prof Grace Grima
Director General
Directorate for Quality Standards in Education

Mr Elton Micallef
Malta Association of Science Educators
(MASE) President

Ms Doreen Mizzi
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Science Teacher
Independent Schools Representative

Prof Frank Ventura
MATSEC Examinations Board &
Faculty of Education
University of Malta

The working group started its work on different fronts:

a) a literature review of the state of science education in various countries, particularly in the EU, to identify the issues and challenges that characterise this area of study;

b) a stocktaking exercise of the state of science education locally – within the various sectors, with the aim of acknowledging and learning from past initiatives, experiences and studies;

c) an exploration of the various science education programmes and resources available on the market to familiarise the working group with the predominant pedagogical approaches for learning/teaching science; and

d) a study of various scenarios for local science education to explore and forecast logistic and training needs, resources and time frames for the implementation of the strategy for science education.

This document is a summary of the main findings and recommendations of this exploratory process.

The State of Science Education

All across Europe, there has been mounting concerns with the type of science education that children and young persons are experiencing.

The state of Primary School Science

While children are expected to develop fundamental scientific concepts, skills and attitudes during the primary school years, studies have identified the following main issues and challenges for primary science within the international sphere (Harlen, 2008; Murphy, Beggs, Russell & Melton, 2005):

- **Many primary school teachers lack confidence in teaching science**, mainly because they are not science specialists.

- **Many primary teachers often choose a traditional approach to science teaching** characterised by the memorization of scientific knowledge, with which they feel more comfortable, over inquiry-based methods that require a deeper and integrated understanding of science. Furthermore, teachers are also faced with heavy workloads which leave little time for meaningful experiments.

- **Primary science should provide more opportunities for open-ended investigation.** Research shows that children reflect about their own direct experiences of the world around them and rarely rely on knowledge they gained in traditional ways at school (Gatt, Tunnicliffe, Borg, & Lautier, 2007; Tunnicliffe, Gatt, Agius, & Pizzuto, 2008). Hence, the need to help primary teachers to develop pedagogies that promote active learner participation in science.

- **Primary science should focus on the natural curiosity of children.** Learning experiences in primary science should begin with careful observation, use of precise language and interaction with a wide variety of natural phenomena (Millar and Osborne, 1998).

- **Learning experiences in primary science** need to be set up taking into consideration new ideas about the way in which children learn. These ideas (Rogoff, 2003; Lave and Wenger, 1991) suggest that children learn within "a learning community". Within the primary science classroom children will learn about science by working with others, by listening to stories about scientists and science and by asking questions about natural phenomena relevant to their everyday experiences.

- **Primary science teaching requires more creative approaches.** Effective pedagogies in primary science, are not simply the direct result of providing adequate resources and infrastructure. They are mainly dependent on the teachers' effectiveness in creating situations which lead young children to ask questions, carry out investigations and experience their environment in a direct way.

- **Teachers lack the required skills to use ICT in the teaching of primary science** (Murphy *et al.*, 2005).

- **A practical approach to science requires a formative approach in assessment.** Good pedagogical practices need to have appropriately developed assessment methods. Murphy *et al*. (2005) show how assessment practices influence the type and quality of the primary science education provided. The principles of assessment for learning, including identifying learning outcomes, giving quality feedback, questioning and the use of self and peer assessment are more adapted to investigative science.

- **Primary science needs to cater for the diversity of students and be based on a gender inclusive pedagogy.** Chetcuti (2009 a) shows how the expectations of teachers for boys and girls varies and that a gender inclusive pedagogy which celebrates differences amongst children enables boys and girls to develop an identity which allows them to develop a positive attitude towards science and the belief that they are capable of learning science at a later level in secondary school.

- **Primary science should allow children to develop the ability to play.** Chetcuti & Griffiths (2002) show how children need to be given the stories, pictures, dances, space and materials for play. This will help the children relate what they are doing in the classroom to real life contexts.

- **Quality primary science can be achieved through both high quality initial training and continuous professional development of primary school teachers** (Murphy *et al.*, 2005).

The observations mentioned above have also been reported in local research that concludes that the current state of science teaching in primary schools is not effective. Besides a reported lack of resources in schools, Maltese primary school teachers are reluctant, and in many cases refuse, to do science. They feel that science is the responsibility of the science peripatetic teachers. Science peripatetic teachers reported that when they called the class teachers were not even present for the science lesson. Consequently there is no follow up or continuity and some pupils have science only once a month. When science is done by the class teacher it is mainly information giving and colouring of worksheets – there is no space and time for investigative science (Chetcuti, 2009 b). Since the 2009-10 scholastic year changes have been implemented and primary classes in State schools have at least two science lessons a month by the science peripatetic teacher.

The state of Secondary School Science

Although the current trend in Europe for science education is two-fold: producing future scientists and providing the rest of citizens with a basic level of scientific literacy, historically, science education focused mainly on the first aim (Osborne & Dillon, 2008). Consequently most science curricula especially at secondary level ended up being loaded with scientific knowledge, and limited time for experimentation and reflection, depriving students from understanding the process and nature of science. Osborne & Dillon (2008) stress that there needs to be a change in the quality and type of science curricula in schools with more space for students to explore the nature of science and how scientists work to understand better how nature works and to develop new technologies.

Murphy (2009) suggests that in the UK there has been a shift in the purpose of science education. Science education is now seen to be an entitlement for all pupils and not for just those pupils who study science. In a presentation given to science students and teachers, Murphy (2009) stated that, "*all young people whatever their future, need a science education to prepare them to make sense of science, whilst appreciating what science has to say about themselves, their environment and the universe.*" This view of science education changes the curriculum for pupils in significant ways. Within such a philosophy, scientific knowledge is seen as a tool to be used to make sense of situations or to solve problems, i.e. functional and useful knowledge. Scientific knowledge is thus extended to include additional tools, i.e. procedures, ways of acting, talking and thinking used when examining the world from a scientific perspective (scientific inquiry).

The philosophy and pedagogy for science education described by Murphy (2009) is not very visible in science classrooms throughout Europe. Rocard, Csermely, Jorde, Lenzen, Walberg-Henriksson and Hemme (2007) claim that the teaching pedagogy adopted in classrooms across Europe is considered as one of the main reasons for which fewer students decide to follow science and technology careers. The heavy content load in science curricula resulted in the widespread adoption of a 'transmission approach' (Sutton, 1992) of teaching that puts more emphasis on what the teacher can deliver and less on what students can actively contribute to their learning.

Once again these international trends were reported locally in a nationwide research project examining the state of science education in all sectors of education in Malta (Pace, 2000 a). The research project revealed that the present system is riddled with the effects of piecemeal strategies and decisions based on intuition rather than on empirical evidence, that have accumulated throughout the years. This history of piecemeal strategies is proving to be the main obstacle restricting innovation in educational institutions and hindering the development of learner-centred pedagogies.

The research project confirmed the international trend concerning a content-oriented science curriculum that caters only for students of high ability and demotivates other students through anticipated failure. This is compounded by the current certification process that fails to acknowledge a wide range of achievement. In Malta, like other countries, the emphasis is on recall of knowledge rather than understanding and internalisation of principles. Consequently arguments were made for the need to develop a holistic science curriculum, contextualised in the learners' experiences, in which knowledge, skills and values are developed and built upon during the various stages of formal education. The report also suggests the development of alternative ways of evaluating proficiency in science, to counter the examination-oriented pedagogy that removes from the science learning experience the excitement and interest that it should generate in learners (Pace, 2000 a).

Contrary to what had been assumed, the research results clearly showed that the number of students following science and applied science courses is increasing in all sectors – including university. However, the number of science graduates gainfully employed is still lagging behind the figures quoted for developed countries. This lag can be easily traced to the drop in science graduates experienced in the late 70s and 80s. Moreover, when considering subject choice at secondary level, students are greatly influenced by their parents' advice, which is determined to a great extent by job prospects (Pace, 2000 a). Nevertheless, subject option choice at secondary level is structured in a way that limits future options in science and students are not given adequate career guidance about science related careers.

Malta's commitment is towards investing resources to ensure good quality science education. However, because of the increase in the population of science students and a desired reduction in learner-teacher ratio, it is quite clear that, besides investing in material resources, education authorities need to invest considerably in human resources and attract more students to become science teachers (Pace, 2000 a). Table 1 shows the number of science teachers and the respective area/s of specialisation in which they graduated.

The Trends in International Maths and Science Survey (TIMSS) in which Malta participated for the first time in 2007 with the Form 3 students, highlighted some concerns in the area of science education. Our country achieved 30th place in science achievement amongst 49 participating countries. Nearly all other participating EU countries attained a better placing than Malta. The survey showed that 23% of our students achieved at the Low Benchmark. The Low Benchmark is the lowest range of scores at which a proficiency level can be determined and that students may obtain in this test. Moreover, 29% of our students achieved below the Low Benchmark i.e. they could not be assigned a level of proficiency in science. When these percentages are added together the results show that 52% of our student population are at or below the Low Benchmark.

On a positive note, the TIMSS survey showed that 5% of our students performed at the Advanced Benchmark compared to the international average of only 3%. The Advanced Benchmark is the highest range of scores that students can obtain in these tests. The survey also showed that Malta enjoys a relatively young and highly qualified cohort of science teachers. The report also underlined that countries which achieved top results in TIMSS rely heavily on students doing frequent practical science activities, have good laboratory facilities and provide students with a safe environment conducive to learning (Mullis, Martin and Foy, 2008).

Besides presenting a vision for science education, the following pages of the report propose curricular structures, guidelines and targets that collectively provide a practical framework for a renewed science curriculum that adequately prepares Maltese learners for the future.

Table 1: Number of science teachers and the respective area/s of specialisation in which they graduated (as in May 2010).

Main area/s	State Schools	Church Schools	Independent Schools	Total
Biology	17	11	5	**33**
Chemistry	9	6	1	**16**
Physics	82	28	9	**119**
Science	16	7	2	**5**
Biology & Chemistry	21	13	3	**37**
Biology & Science	21	6	2	**29**
Chemistry & Science	13	5	1	**19**
Physics & Chemistry	14	5	0	**19**
Physics & Biology	9	1	0	**10**
Physics & Science	25	7	0	**32**
Others	15	15	21	**51**
Total	**242**	**104**	**44**	**390**

Vision Statement

An educational system
that provides all learners
with the scientific knowledge and understanding necessary
to help them function within the context of
a dynamic world characterised by continuous change.

Science and technology do not just affect our social and cultural contexts, but they are the main driving force of change. This change can lead to further progress and prosperity, but it can also threaten the sustainability of living conditions depending on the decisions that we make individually and collectively as a community.

The Purposes of Science Education

It is important **to develop the scientific literacy of all learners**, enabling them to make informed decisions as they strive to improve their quality of life and to understand the changing contexts. Knowledge of science affects the choices we make for healthy living; the prevention and treatment of disease; energy use and living in safe and comfortable homes; transport and communicating with others; and other everyday life decisions. Science also helps us to answer questions that have intrigued human beings for many years and which are still unresolved. Curiosity drives us to ask questions about the origins of the universe, the stars, the Earth, the elements, life on Earth, the diversity of life, the possibility of life on other planets, the future of the planet, and other questions. Science education provides an opportunity for learning what scientists have done and what they are doing to answer these questions and enables students to consider the ethical and moral implications of science. Furthermore, scientific literacy empowers citizens to initiate change and actively participate in decision making fora.

Besides imparting knowledge, science education also **develops skills and ways of thinking that are important for decision-making and problem solving using an evidence-based approach**. These include inquiry, observation and accurate measurement, critical thinking, considering alternative interpretations, and communicating conclusions. An education in science also serves to develop and strengthen attitudes and values that are important for living in a democratic society. Curiosity, respect for evidence, honesty, open-mindedness, healthy scepticism and critical reflection are essential in science and necessary in all aspects of everyday life. The relevance of scientific skills, attitudes and values becomes evident when science curricula take into consideration the social, ethical, cultural and historical contexts of science and its applications.

Science education also needs **to provide a strong foundation for learners who wish to pursue a career in science and other science related careers** that require them to focus on science at post-secondary and tertiary levels. These specialists are needed to operate the scientific and technical systems on which our quality of life depends. Other specialists are needed to create innovative systems of working and new products that are essential for national prosperity and economic development.

To address these purposes, our educational system has to be flexible enough to allow all learners with the potential of following a career in science or a science- related profession to do so at any point in their schooling. It also implies an inclusive educational setting that acknowledges, caters for and validates a whole range of abilities: from low to high achieving students.

Realising the vision

This vision can be realised by providing quality science curricula that:

- allow all students to develop scientific literacy;
- provide opportunities for engaging with and exploring the natural environment;
- are based on a pedagogy which is varied and creative;
- cater for the individual needs of students and draw on contexts which are familiar to both girls and boys;
- provide assessment opportunities which allow learners to show what they know and can do;
- allow students to engage with science in a context relevant to everyday life experiences;
- provide opportunities for learning about science and scientists within a historical and cultural context;
- allow students to gain an understanding of science and the processes of science within "a learning community"; and
- provide opportunities for learning science in both formal and informal contexts.

The effectiveness of these curricula is enhanced when strong links are made with the work done in the Early Years[2], between the primary and secondary education curricula and with the post-secondary science curricula. By co-ordinating the work at all levels, unnecessary repetition is avoided and age-appropriate subject content and skills can be emphasised. In practice this means that:

- during their early years children are provided with different environments and opportunities that stimulate their curiosity; develop their observation skills (by identifying similarities and differences, observing change and patterns in events); support and promote a sense of inquisitiveness; learn how to ask questions about how and why things work; and how to investigate objects and materials and their properties.
- at the primary level, all learners can follow a core science curriculum which offers flexibility so that individual schools develop their own programmes based on issues and themes that are particularly relevant to their school community.
- throughout the secondary level, science will continue to be a fundamental component of the curriculum allowing learners to explore scientific concepts through a thematic approach. All students in Forms 1 and 2 will follow the Core Science curriculum that will

2 The Early Years refer to children from birth to the age of seven implying that early childhood education and care starts in the home, is experienced in non-compulsory and informal settings including child-care and kindergarten, but is extended into the first two years of compulsory primary school.

provide a good foundation for further studies in science. The Core Science programme will continue to be offered to students, in Forms 3, 4 and 5, who do not wish to specialise in science. This ensures that all learners acquire an adequate level of scientific literacy.

- in the higher forms of secondary level, learners may wish to study science in more detail or aim at a career in science or a profession that requires a deeper knowledge of science. For these students, the science curriculum needs to offer options that allow them to:

  i. choose increasing degrees of exposure to science education based on their personal interest and abilities; and

  ii. follow specific directions that reflect personal preferences and/or possible future career inclinations and choices.

- a smooth transition from secondary to post-secondary level may require a study of the possible paths followed by students at post-secondary level, how the gap between curricula at the two levels can be minimised and how post-secondary education is organised. It is pertinent, at this point, to re-propose a model (shown in Figure 2) proposed by Working Group 7 of the National Steering Committee on the Implementation of the National Minimum Curriculum (Pace, 2000 b). The model can only be worked out after a restructuring of the Intermediate level and the Advanced level syllabi. In this restructuring exercise the syllabi have to be (a) structured in a modular format, and (b) viewed as a continuous programme (e.g. two core modules at Intermediate level and four modules at Advanced level).

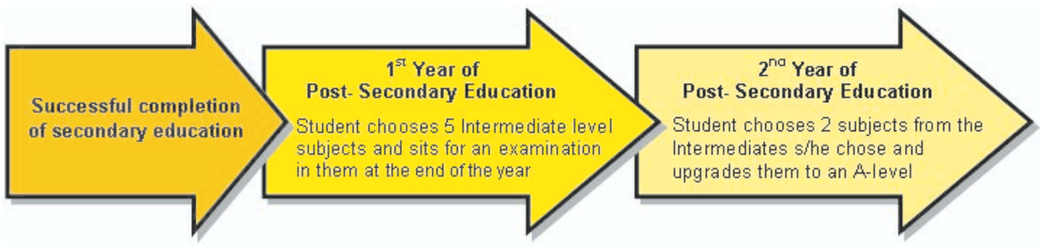

Figure 2: *Scheme showing how the smooth transition from secondary to post-secondary level can be achieved*

The Secondary School Science Curriculum Structure

Realising the vision necessitates an overall rethink of what constitutes science education at the various levels of schooling. However, the major change proposed is in the way science education is organised, taught and learnt at the secondary level. At the secondary school level, the curriculum will be organised as shown in Table 2.

Table 2: The science curriculum at secondary school level

Forms	Core/Option (number of lessons/week)	Student group
1 & 2	Core Science (4)	All students
3, 4 & 5	Core Science (4)	Core Science programme
	Materials Science (4) + Physical Sciences (4)	Science Option 1
	Materials Science (4) + Life Sciences (4)	Science Option 2
	Physical Sciences (4) + Life Sciences (4)	Science Option 3
	Materials Science (4) + Physical Sciences (4) + Life Sciences (4)	Science Option 4

All students in Maltese schools are entitled to learn science in order to obtain a basic scientific literacy which will enable them to make informed choices and decisions about science as citizens. The basic concepts of science will be organised around three main strands:

- developing scientific understanding;
- developing scientific inquiry skills; and
- being able to relate science to technology, society and the environment.

These strands will be dealt with in **all** the science options offered, i.e. Core Science, Materials Science, Physical Sciences and Life Sciences. In the Core Science programme the basic core concepts of science will be dealt with through these three strands. The Materials Science, Physical Sciences and Life Sciences programmes will deal with these basic core concepts and continue to build on them in more depth.

In Forms 1 and 2 all students follow the same course in **Core Science** with 4 lessons a week. This course will be on similar lines as the current Integrated Science course, but there will be more emphasis on inquiry and the processes of science. During this phase of secondary education, the pedagogy and the subject content introduce students to basic scientific concepts and the processes of science and motivate them to look forward to science at a higher level, i.e. in the next phase of their secondary education. An important aspect of **Core Science** will be the presentation of “Key Science Ideas” and allowing the students to look at these “Key Science Ideas” in terms of their historical development, their contribution to scientific knowledge and their relevance in everyday life.

From Form 3 onwards, students who do not want to specialise in science will have **Core Science** with 4 lessons a week.

In Form 3, some students may choose to study **any one** of the following options with a total of 8 (4 + 4) science lessons per week:

- **Materials Science and Life Sciences**
- **Materials Science and Physical Sciences**
- **Physical Sciences and Life Sciences**

Other students may wish to opt for **all** the science subject areas, providing them with a wider choice of possible careers in science for which they can aim. This amounts to 12 science lessons a week: 4 lessons in Materials Science, 4 lessons in Physical Sciences and 4 lessons in Life Sciences.

Figure 1 provides a graphic representation of the various science options.

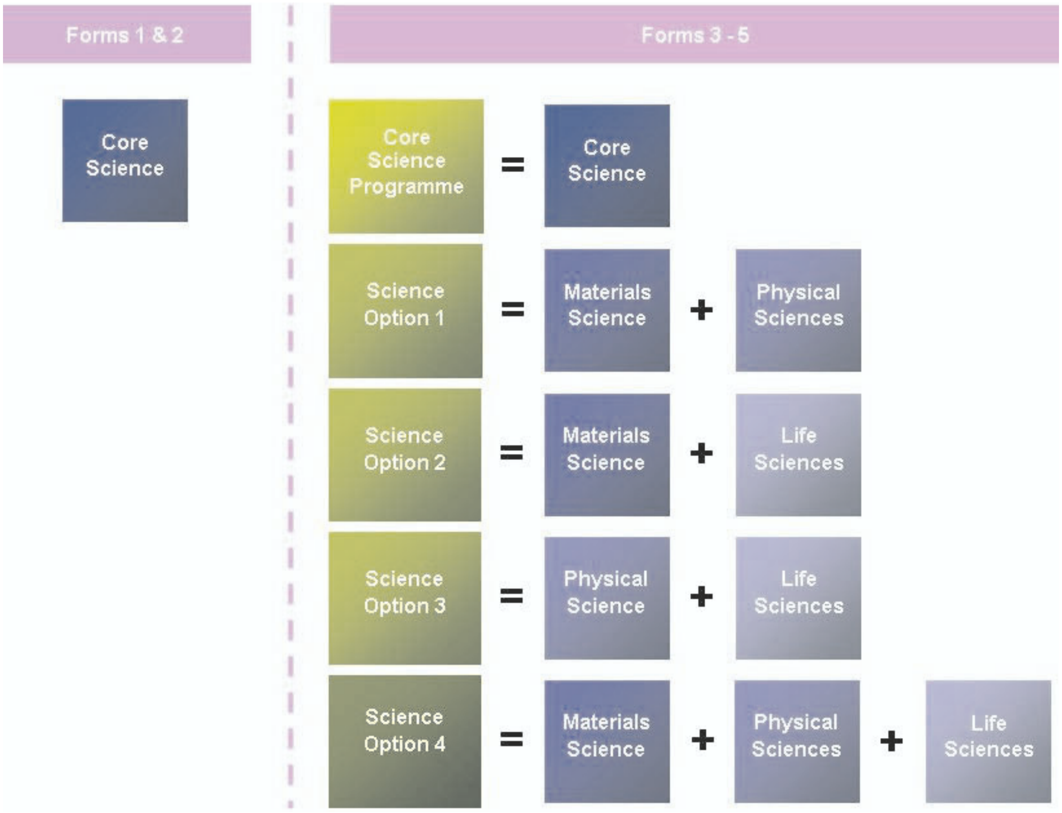

Figure I: *The various Science options on offer in the curriculum*

Secondary School Science Curriculum Content

The **Core Science** will help students attain scientific literacy by providing them with a balanced view of science covering a range of concepts, principles, theories and methods of investigation. The content will be organised in themes bringing together knowledge from different areas to show the coherence of science and the need to use concepts from different sciences to understand natural phenomena and to solve everyday problems.

The **Materials Science** curriculum will focus on a variety of natural and synthetic materials, their chemical and physical properties and uses in everyday life and natural processes. It will deal with the structure of materials, their properties and reactions. It will also focus on how different materials can be created and combined in different ways to develop new products that improve the quality of life and the application of materials in different fields.

The **Physical Sciences** curriculum will provide more detailed explanations and applications of the physical and chemical concepts and principles in everyday life. It will mainly deal with matter, energy and the interactions between them on the microscopic scale, and with the formation and evolution of the Earth, the Solar System and the Universe on the macroscopic scale.

The **Life Sciences** curriculum will help students to study in greater depth the biological and related chemical concepts. It will deal mainly with organisms, their structure, functions and interactions with the environment on microscopic and macroscopic scales thus presenting a systemic perspective of life on our planet.

A cursory view of the proposed change might give the wrong impression that Materials Science, Physical Sciences and Life Sciences are just a cosmetic change of the science subjects currently offered (Chemistry, Physics and Biology). The new vision for science that is being proposed is a paradigm shift in the way science is currently taught. It implies a methodology that promotes inquiry-based learning that requires a deeper and integrated understanding of science and how scientific knowledge is structured.

The detailed syllabi for Core Science, Materials Science, Physical Sciences and Life Sciences will be drawn up once the proposals of this strategy are agreed to in principle.

Inquiry-based science education

In December 1995, the US National Research Council (NRC) released the National Science Education Standards based on a vision of science education that would make scientific literacy for all a reality in the 21st century.[3] Inquiry is a central theme of the document. The term "inquiry" was used in two different ways in the document, referring to:

a) the abilities students should develop to be able to design and conduct scientific investigations and to the understandings they should gain about the nature of scientific inquiry; and

b) the learning and teaching strategies that enable scientific concepts to be mastered through investigations.

In this way, the document drew connections between learning science, learning to do science, and learning about science. Subsequently, a committee was set up to draw up a practical guide for teachers, professional developers and administrators. Inquiry-based learning should achieve the following skills and competences in science (National Research Council, 2000):

- the ability to ask questions about objects, organisms and phenomena in the environment. Students learn to answer their questions by seeking information from reliable sources of scientific information and from their own observations and investigations;

- learn how to plan and conduct simple investigations. Students learn how to design and conduct simple and fair experiments to answer questions;

- use equipment (including computers and calculators) and tools to extend their senses and gather data;

- use data to construct reasonable explanations. This skill implies that students develop a critical approach to data collection and hypothesis formation and testing; and

- communicate, critique, and analyze their work and the work of other students.

Although these aspects of inquiry can be achieved through different approaches and pedagogies, it is important to promote active learning. Learners are actively engaged in investigations and involved in working out meanings and explanations in groups – through the social construction of knowledge (Gatt & Vella, 2003). These are approaches that engage learners physically, mentally and socially to different degrees, but with the result that learners understand not only scientific knowledge, but also what it means to do science.

3 http://www.nap.edu/catalog/4962.html

A model for Learning and Teaching Science

The vision of science education outlined needs to be accompanied by a shift in the pedagogical processes used in the science classroom. It also needs to be accompanied by a shift in our vision of learning towards sociocultural learning theories which emphasise the importance of sociocultural experiences in influencing development (Rogoff, 2003). New ideas about learning suggest that students learn best when they engage with each other and learn from one another. Within this perspective, learning occurs in a "community of practice" (Wenger, 1999; Lave, & Wenger, 1991).

The model of instruction which best reflects these ideas about learning is inquiry-based learning which involves the use of a planned sequence of instruction that places the students at the centre of their learning experiences, encouraging them to explore, construct their own understanding of scientific concepts and relate to other concepts (Ansberry & Morgan, 2005). This model known as the 5E model allows pupils to Engage, Explore, Explain, Elaborate, and Evaluate. Jorgenson, Cleveland and Vanosdall (2004, p.19) describe this process:

"*The teacher first determines the topic of inquiry and provides a discrepant event or focus question or problem to* ***engage*** *student interest and curiosity. The students, with their teacher as guide and coinvestigator, begin to* ***explore*** *the problem or question. They make further observations and attempt to* ***explain*** *the phenomena they observe. The teacher then challenges students to* ***elaborate*** *on their understandings by linking observations to prior knowledge and by applying the concepts and skills in new situations. Finally, the teacher encourages students to* ***evaluate*** *their understandings and abilities, and the teacher evaluates or assesses the areas of strengths and weaknesses exposed by student performance in the activity*".

This model moves away from the traditional *transmission* model of teaching to a more *interactive* one where the students take on greater responsibility for their own learning. The teacher also assumes a different role and rather than giving information, the teacher acts as a guide providing the opportunities for learning to occur (Ansberry & Morgan, 2005). The teaching methods also change. The focus on lecturing, providing answers to questions, and testing isolated facts is replaced by practical work to achieve conceptual understanding, simple investigations to explore variables, application of concepts to everyday life, using secondary sources of information such as newspaper or magazine articles, and the use of role play to provide insights into how students are making sense of evidence and connecting their learning to real situations (Murphy, 2009).

Learning and teaching science should also be based on a "gender inclusive pedagogy". Such a pedagogy as described by Parker and Rennie (2002, p. 882) should be based on:

"*a supportive learning environment which emphasises communication, interpersonal negotiation, interaction amongst all participants, harassment free discussions, active participation by students; second, real-life contexts; third, school-based, informal assessment procedures, with relatively open-ended tasks drawing on contexts which are familiar to both boys and girls; and fourth, attention to the students' self-awareness of the extent to which their education related decisions and experiences are socially constructed … The pedagogy and assessment procedures should take account of the diverse ways of knowing, viewing and describing the world*".

Assessment

Assessment is for learning

Assessment should take place alongside learning and provides students with continuous, qualitative feedback which allows them to grow and move forward in their learning. Students need to be made aware of the learning outcomes towards which they are working, the method by which they will be assessed and the criteria or marking scheme on which their work will be assessed. Students learn how to assess individual experience within the class community and they begin to develop a sense of what it means to do science and to be a scientist. For learning to occur, assessment also needs to be a participatory activity and allow learners to be able to assess their own work and the work of others. This allows learners to become autonomous and to take responsibility for their own learning.

The planned science curriculum will identify general learning outcomes for science which focus on understanding, investigating, communicating, linking and applying science. These learning outcomes and the levels of achievement identified for each learning outcome will help the teacher and the student assess progress. Learning outcomes can be captured and recorded through various forms such as:

1. Investigations and problem solving activities: The pedagogy advocated in this vision for science education focuses on inquiry-based learning and the development of problem solving skills. There is emphasis on the processes of science rather than solely on content knowledge. It is therefore important that assessment methods used provide feedback on the various skills which students manage to develop such as using equipment in the correct manner, being able to follow instructions, being able to record and interpret results as well as to research and present information in an organised way.

2. Learning logs and portfolios: Learning logs allow students to think about their own learning and to record skills and concepts which they have learnt. It allows them to trace the development of thoughts and ideas. The portfolio can be a more extensive record of progress throughout the secondary school years of students. In the portfolio students may keep examples of work which they have carried out and which shows their success and achievement in science.

3. Self assessment which allows students to gain a better understanding of what they have managed to achieve.

4. Peer assessment which allows students to share expertise in the classroom and to learn from collaboration with others.

5. Formal tests and examinations: The summative assessment of learning also needs to take place hand in hand with the formative assessment of students. The end of year assessment can give an indication of the skills and knowledge gained by students at the end of a course of study or at the end of a particular module of study.

At the end of secondary schooling

Students may opt to sit for their Secondary Education Certificate (SEC) Examination, at the end of their secondary education, in the following subject areas: (i) Core Science; (ii) Materials Sciences, (iii) Physical Sciences and (iv) Life Sciences. The results of each of these examinations will be recorded and certified as separate examination subjects.

For each of these subject areas there will be a Paper I which is to be taken by all students and a Paper II which may be a Paper IIA or IIB. Students may opt for either Paper IIA which will be more difficult than Paper I or Paper IIB which will be easier than Paper I. There will also be 15% of the marks which will be allocated to the assessment of practical work which may include a portfolio of investigative work carried out by the students, an oral presentation of key ideas and/or a practical examination.

Each of the syllabi of these SEC examinations (Core, Materials, Physical and Life Sciences) will satisfy the requirements to enter post-secondary education.

A small proportion of students may not be able to reach the required standard at SEC level. For these students, certification of their attainment in science can be provided either internally by the school or externally or both. The school records the students' attainment in the Secondary School Certificate, which is already recognised as a Malta Qualifications Framework Level 1 qualification by the Malta Qualifications Council. External certification can be provided when the certification of functional competences in the basic subjects at a different level from SEC as proposed in the 2005 MATSEC Review is implemented (MEYE, 2005, p.95).

Learning Outcomes

… for the Early Years

In keeping with characteristics of how young children learn and extend their understanding of the world around them, science in the Early Years potentially offers a wealth of opportunities which can be easily introduced and developed with three, four and five-year-old children.

Young children are naturally curious and eager to find out how things work and function. As a result of their limited experiences, in their journey of enthusiastic discovery about the world around them, children use all their senses to acquire new information as well as to expand their prior knowledge about themselves, their immediate environment, within and outside the home as well as their surroundings. Thus children learn from a young age to associate science to natural, observable phenomena which happen in daily routines.

In keeping with Piaget's notions of learning through assimilation and accommodation, any opportunities where children observe, examine, try things out, predict, hypothesise and ultimately obtain results, allow them to develop schemata and networks which help them to make associations, remember, recall, understand and consequently develop cognitively and intellectually. Simultaneously, children are developing in other areas. For example, as they engage with observing objects, events, animate and inanimate things, children's language development matures through the questions and answers which they seek or provide; their vocabulary is extended as they acquire labels for objects they encounter. Observation requires children to "*slow down, focus on details and construct meaning – skills essential to the reading process as well as scientific inquiry*" (Cowan & Cipriani, 2009). Basic concepts related to data, shapes and measurement begin to emerge as they make comparisons, discover patterns and identify properties of objects. Gross and fine motor skills develop as children are engaged with handling materials and equipment as well as invited to have visual representations of what they have observed.

Successful science activities can be promoted both in the indoor and outdoor environments. Environments need to "*inspire active investigations*" which "*invite children to try out their ideas*" (Zan & Geiken, 2010). Having a discovery area in the classroom with materials which encourage children to become engaged and involved as well as conducting out-door activities where children can look for and observe natural phenomena should contribute to a rich Early Years programme. Children can easily begin to identify properties and characteristics (e.g. sand, rocks & shells; leaves, seeds & flowers); observe and keep records (e.g. weather patterns – rainy, cloudy, windy, sunny days); gain insights into concepts of weight, volume, gravity and pressure (e.g. through water play, with funnels, containers, rubber tubing); read or listen to excerpts from articles/books/newspaper leading to a discussion about environmental issues and possible solutions (e.g. waste and conservation of paper, electricity, water).

Science lends itself very easily to the Early Years settings: in their attempts to understand the world, young children engage with meaningful, relevant and purposeful activities. The world of science can indeed be a catalyst to invite children to take an interest, become engaged and engrossed in finding out the why and how things happen in natural rather than an artificial or contrived manner. Science is relevant as it occurs in children's own environments regularly and daily and consequently, it is purposeful for children in that meaningful explanations for naturally occurring phenomena can be obtained.

Doing science at the primary school level for children aged 5 to 10+ through to the secondary level for young students aged 11 to 16 involves:

- **Understanding** the world around us by asking questions about it, seeking ways of answering these questions, and developing knowledge that helps us to understand nature and to improve our quality of life;

- **Investigating** phenomena and processes by planning investigations, making predictions, deciding how to check predictions fairly, making observations and taking accurate and reliable measurements, analysing the evidence obtained, critically evaluating evidence, and drawing conclusions;

- **Communicating** scientific knowledge by means of oral, written, graphical and other appropriate means using scientific language, that is terminology, conventions and techniques appropriate to the task;

- **Linking** science to everyday life and **Applying** the scientific knowledge gained to explain natural phenomena and how things work, and to enjoy an improved quality of life.

... for Primary Education

The purpose of teaching science to primary school children should be to create awareness and develop a sense of wonder about the world and interest in science activity in the world and how it informs and shapes their lives. Science becomes a subject that older primary children, both boys and girls, find relevant and valuable. At primary level, the main focus should be on children participating in meaningful science activities that allow them to connect with the natural world around them and allow them to acquire a sense of their own competence in understanding and doing science.

Learning science can be done through play and other enjoyable hands-on activities, with an emphasis on observation and communication of their experiences rather than on explanations that require the use of abstract ideas. Students can be encouraged to engage with science through:

- investigations which allow them to ask questions, observe, gather data and draw conclusions;

- discussions and the use of multimedia resources to find information; and

- the use of storytelling and drama in order to link science to daily living and the local environment in which they live.

Assessment of student success should take place alongside learning and involve situated problem solving activities. It should be formative in nature and based not only on individual achievement, but include group and self assessment. This allows students to develop a sense of themselves as "young scientists" within their class community. Learning outcomes can be captured and reported through various forms of recording such as investigations, learning logbooks and portfolios. The assessment should be a narrative account or "learning story" which documents the skills and processes of science as they are experienced by the learner.

Learning and Assessment need to take into consideration the diversity of children. Children bring with them into the science classroom different needs, backgrounds, talents and attitudes. These differences need to be valued and in the science classroom children need to feel safe to explore their identities and play with different roles; listen to stories about scientists; and be allowed to express themselves through a variety of learning activities. These multiple forms of teaching resources, learning styles and forms of assessment will allow all children to show what they know, understand and can do (Chetcuti & Griffiths, 2002).

… for Secondary Education

The purpose of teaching science to secondary school children, besides sustaining the students' interest and engagement in science, should be to develop an understanding of the natural world and ensure the progression in scientific thinking and innovation as well as seeing how science relates to their lives. More formal teaching methods are suitable at this level and investigations should feature strongly as hands-on and minds-on activities. Communicating science at this level gradually becomes more formal and includes the use of mathematics and mathematical techniques at the appropriate level. An understanding of the link of science with everyday life may not simply consider scientific principles, but also other issues such as ethical, economic, social and moral issues. This dimension should help students to integrate knowledge from different learning areas and understand that science does not have a solution to all problem situations.

The secondary school science curriculum is organised into four options, i.e. Core Science, Materials Science, Physical Sciences and Life Sciences with each option differing in the level of exposure to science a student gets. Although the exposure to, and hence the experience of, doing science varies from option to option, students following any one of these options are expected to achieve the learning outcomes at the appropriate level.

Learning experiences in secondary science should vary and focus on the processes of science in addition to content knowledge. Learning should include opportunities for individual and group activities. Students are encouraged to **engage** with science through investigations, use of multimedia resources, and use of secondary resources such as science magazines and newspaper articles; to **explore** science by planning, setting up and carrying out experiments in order to answer questions and solve problems; to **explain** concepts, principles and theories using observations of phenomena they have made and recognise that principles and theories were developed within a historical context; to **elaborate** on their explanations using the proper scientific language and techniques such as tables, charts and mathematical methods; and to finally **evaluate** their own learning and group processes in relation to everyday life.

Assessment is for learning. Students learn how to assess individual experience within the class community and they begin to develop a sense of what it means to do science and to be a scientist. Assessment should take place alongside learning and provides students with continuous, qualitative feedback which allows them to grow and move forward in their learning. Learning outcomes can be captured and recorded through various forms such as investigations and problem solving activities, learning logbooks and portfolios, in addition to more formal summative assessment. Assessment should not be based solely on individual achievement, but also include self and peer assessment.

The implementation of the new science curricula requires

- the production / selection of interesting and attractive curriculum materials. The careful use of eLearning platforms and other digital media, students'/teachers' guides and reference materials should be primary sources of information for learners and teachers. These resources provide the necessary guidance about the expected levels of achievement and effective pedagogy. This is especially important at the primary level where teachers may not be confident enough in teaching a subject which they studied years before at secondary school level. This is particularly needed to offer support to teach topics with which teachers may not be familiar.

  The working group inspected a number of textbooks and also met with textbook publishers about the books available. The textbooks were of a high quality, but they need to be adapted to the Maltese context and according to the themes selected for Core Science, Materials Science, Physical Sciences and Life Sciences. Apparently, these adaptations can be negotiated with the publishers who are willing to make the necessary changes and write new units if required. The cost, the timeframe and any conditions involved need to be negotiated.

- adequate laboratory facilities, ICTs, equipment, chemical and biological resources, as well as suitable software, learning guides and other curriculum materials that are relevant to the local context.

- finding ways of dividing classes for science lessons with the aim of increasing the opportunities for students to carry out hands-on activities that are essential for inquiry-based learning. It is planned that Form 1 students will start benefitting from such an arrangement as from September 2011. Phased in over two years such an arrangement will cover both Forms 1 and 2 by September 2012. Although Form 3, 4 and 5 students studying Physics, Biology and Chemistry are already being grouped in this way, the new model will further increase the number of science groups and hence the number of teachers of science that will be required. It would therefore be imperative to phase in the reform over a period of five years, starting at Form 1, so that the demand on human capacity will start to be felt in the third year and will increase gradually over a period of a further three years.

A major advantage of the reform is that it will provide the system with more teaching practice placements for undergraduates training to become science teachers. Currently the educational system is caught up in the vicious circle that while supply is not meeting demand, at the same time, schools are not in a position to offer more teaching practice placements. This new model can break us free from that constraint.

In the meantime, the country needs to extend the number of incentives to whoever opts to become a science teacher. Apart from continuing to offer a higher stipend during initial teacher education years one should actively consider introducing incentives like doubling the allowance (paid to teachers) to all newly appointed teachers of science subjects for the first years of their career.

- professional and creative timetabling skills due to the constraints that the reduction in class size and the number of science options available have imposed on the exercise. Catering for the new timetabling demands necessitates giving priority to the science options over other timetabling limitations.
- the support from education officers, college principals and heads of school, heads of departments, primary science support teachers, and laboratory technicians.
- the adequate preparation of science teachers. This entails a review and the strengthening of the initial science teacher education course and an evaluation of the current in-service courses with a view of improving the continuing professional development programmes for practising teachers.

Currently science teachers can be teaching Integrated Science in Forms 1 and 2, Biology, Chemistry or Physics in Forms 3, 4 and 5 or a combination of all of these. **All teachers need re-training in methods of teaching since the proposed curriculum emphasises the inquiry approach to learning.**

Re-training is also needed to enable teachers to teach certain aspects of content which they have not taught for a number of years because they were teaching a single science subject or because the content is new. Table 3 lists the projected training needs in content matter (as in May 2010). The compilation of the data assumes that teachers who graduated in:

- 'science' - do not need any further content training;
- either Physics or Chemistry or Biology - require content training in the two other areas;
- two areas of science - require content training in the remaining area.

Table 3: No. of teachers who need content training in:

	Biology	Chemistry	Physics	No. of teachers who do not need any content training
State Schools	97	109	47	75
Church Schools	39	40	30	25
Independent Schools	10	14	9	6

About a quarter of the teachers' cohort teaches Integrated Science and another quarter has qualifications in two sciences. These can be easily re-trained to teach Core Science and any one of Materials Science or Physical Sciences or Life Sciences depending on their qualifications and inclinations. Half of the teachers' cohort, mainly Physics teachers, has qualifications in Mathematics and Physics. These can be trained to teach Physical Sciences, which include concepts and principles from the current Physics curriculum, and mainly Physical Chemistry and Earth Science concepts and principles.

A continuous professional development programme can be organised to obtain feedback from teachers, to review and evaluate the implementation of the new science subjects and to suggest ways of tackling any difficulties that may arise.

Time frame for the consultation process

Date	Task
Mar 2011	Finalisation of draft Science Strategy Document and dissemination among critical friends for feedback
Apr 2011	Publication of Science Strategy Document for consultation
May – Dec 2011	National Consultation process
Jan 2012	Finalization of Science Strategy Document

Targets

With these changes, science education should produce distinctly better outcomes than the current results. Improvement can be assessed by using the following indicators:

- Malta will improve its performance in the TIMSS and PISA surveys in science achievement. Malta will obtain a better placing and an improved average score mark in science achievement, among the participating countries;

- a significant reduction of the percentage of the students' population that achieve at or are below the Low Benchmark of science achievement in the TIMSS survey - currently standing at 52% of the cohort; and

- an increase in the number of students who:

    - take up the science option (i.e. Materials Science, Physical Sciences and Life Sciences) at secondary level;

    - sit for the SEC examinations in science;

    - study one or more science subjects as part of their Matriculation Certificate; and

    - read for under-/post-graduate degrees in science and/or science related areas and carry out research projects that attract more funding from local and foreign sources.

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