New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION


Changing the Chemistry Curriculum at Secondary level: opportunities and challenges

Josette Farrugia[1], Doreen Mizzi[2], Richard Zahra[3], Dennis Zarb[4]

Abstract

The science curricula in Malta, have for years focused mainly on scientific knowledge. In addition, high stakes national examinations tend to encourage teaching to the test and teacher-centred instruction tends to predominate in many science classrooms. The chemistry programme, for example, presents the subject in a rather fragmented way that is abstract, encourages memorization and is irrelevant to students' everyday lives. In 2012 a new National Curriculum Framework was published in Malta. This led to the development of a Learning Outcomes Framework for the different school subjects up to compulsory school age including a new programme for chemistry. The new programme is organized around five themes and aims to provide students and teachers with time and space to engage with the subject, encourages student-centred learning and includes practical work as an integral part of the programme. As for all educational reforms, teachers will be key players in the proposed change. This paper reports a study that investigated teachers' views about the proposed programme, challenges envisaged and support required in its implementation. Teachers regarded the change as an improvement due to the shift of focus on to students' learning and the attempts to make the subject less abstract and more relevant. Yet there were many concerns about its implementation in particular school settings and about whether the new programme would have to fit in the current timeframe and assessment system centred around high stakes examinations. It is important to ensure that policies, especially assessment policies, support the proposed changes and that teachers are given the required support. This will increase the likelihood of successful implementation.

1. Introduction

Like many European countries, Malta has experienced a severe decline in the popularity of chemistry at secondary level (age 14-16). The number of students sitting for the end of secondary education examination in chemistry has dropped by 15% between 2004 and 2015.

The existing science curricula in Malta, and the chemistry programme in particular, focus mainly on knowledge and much of the teaching is limited to transmission of knowledge. High stakes examinations at the end of compulsory education tend to encourage teaching to the test in traditional classrooms through teacher-centred instruction. The current chemistry programme [1] presents chemistry as a rather fragmented body of knowledge that is abstract, encourages memorization and is irrelevant to students' everyday lives. In fact the syllabus document divides the content into four major areas:

- Facts of chemistry
- Principles of chemistry
- Chemistry, Society and the Natural Environment
- Chemical Laboratory Experience

The most prominent section is that about Facts of Chemistry followed by Principles of Chemistry. For years, educators have felt the need to move towards a curriculum that is relevant to students and through which "knowledge, skills and values are developed" [2:2]. This view is shared by numerous educators from different countries [3].

In 2012 the new National Curriculum Framework [4] was published which led to the development of the Learning Outcomes Framework (LOF) [5] for the different subjects studied at compulsory school

[1] University of Malta, Malta
[2] Secretariat for Catholic Education, Malta
[3] Institute of Applied Sciences, MCAST, Malta
[4] Giovanni Curmi Higher Secondary School, Malta

age. This includes a new program for chemistry, that aims to help students develop scientific understanding; scientific inquiry skills; and ability to relate science to technology, society and the environment as recommended by the document titled: A Vision for Science Education in Malta [6] which in turn is in line with recommendations made in other countries (e.g. [3] [7] [8] [9]).

The new programme [5] is organized around five themes with materials from students' surroundings as the starting points:

- Materials from the Earth: the atmosphere
- Materials from Earth: the sea
- Materials from the Earth: the land
- Making New Materials - How fast? How far? How much?
- Carbon compounds from the Earth - Meeting our energy needs

Chemical principles, trends and concepts are introduced through these five themes. The four main activities and essential questions that characterize the subject are those summarized by Talanquer [10] namely: analysis, synthesis, transformation and modelling. The programme aims to provide students and teachers with the time and space to engage with the subject rather than simply provide them with a mass of factual knowledge as well as provide students with the opportunity to develop critical thinking and inquiry skills by encouraging inquiry based learning together with other student-centred approaches. Practical work is an integral part of the programme with opportunities for inquiry and investigations that provoke thinking and discussion rather than experiments to confirm and prove theory. The programme also recommends assessment practices that go beyond summative tests and examinations. The learning outcomes (LOs) outlined cover a range of competences and skills. Figure 1 shows a number of LOs linked to the theme Materials from the Earth: the Atmosphere while Figure 2 shows a mind map linking the principles, concepts and other content tackled under the theme Materials from the Earth: land.

Subject Focus: Materials from the Earth - The Atmosphere
Learn about the natural constituents of the atmosphere as well as polluting chemicals. Use the properties of these substances to construct groupings and understand patterns of physical and chemical behaviour.

1] I can identify the gases that make up the air naturally and those that may be added by humans *e.g. nitrogen, oxygen, carbon monoxide, carbon dioxide, water vapour, noble gases, sulfur dioxide, nitrogen oxides.*

LEARNING TO KNOW

2] I can describe the properties of nitrogen, oxygen, carbon dioxide and noble gases as well as relate these properties to uses of the gases.
3] I can use the periodic table to describe and/or model atoms showing differences between atoms *e.g. subatomic particles - protons, neutrons and electrons; atomic number, isotopes and relative atomic mass.*
4] I can determine the electron configuration of a given atom using the periodic table *e.g. of the first 20 elements.*
5] I can explain where to find the gaseous elements in the periodic table.
6] I can use the online periodic table to find information about elements and identify the symbols of common elements in the periodic table *e.g. first 20 elements and bromine, iodine, lead, copper, iron, zinc and silver.*

INFORMATION MANAGEMENT

7] I can explain the difference between elements and compounds *e.g. using gases in air as examples.*
8] I can explain how covalent bonds are formed and represent them using dot-and-cross diagrams *e.g. hydrogen, oxygen, nitrogen, chlorine, methane, water, carbon dioxide, ammonia, hydrogen chloride.*
9] I can describe the properties of simple covalent substances *e.g. melting and boiling points, non-conduction of electricity.*
10] I can use the properties of simple covalent substances to explain how they behave *e.g. fractional distillation of liquid air – no details of industrial process are required.*
11] I can explain the fact that gases have different relative densities and equal volumes of gases, when measured under the same conditions, have different masses *e.g. gases have different diffusion rates depending on their atomic or molecular mass.*
12] I can investigate how gases may be safely prepared in the laboratory and evaluate different collection methods *e.g.carbon dioxide by reacting acid with carbonates: oxygen from hydrogen peroxide; and hydrogen by reacting an acid with an appropriate metal.*
13] I can identify water and carbon monoxide as examples of neutral oxides.
14] I can explain how the amount of certain gases and particulates in the environment may increase due to combustion reactions *e.g. carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen oxides and soot.*
15] I can explain how some gases react with water to produce acidic solutions *e.g. carbon dioxide and sulfur dioxide.*
16] I can interpret data to identify and explain environmental effects of some gases and particulates in the atmosphere.
17] I can discuss methods for reducing emission of pollutants into the atmosphere *e.g. use of renewable sources of energy, catalytic converters.*
18] I can translate the reactions described in this theme into balanced chemical equations.

Fig. 1. Example of LOs linked to the theme: Materials from the Earth – the Atmosphere

As for any curricular reform, teachers will be key players in the proposed change. Teachers' beliefs, views and knowledge must be taken into consideration to increase the likelihood of implimentation.

This study sought to obtain teachers' views about the proposed programme as well as challenges envisaged and support required in implementing the programme.

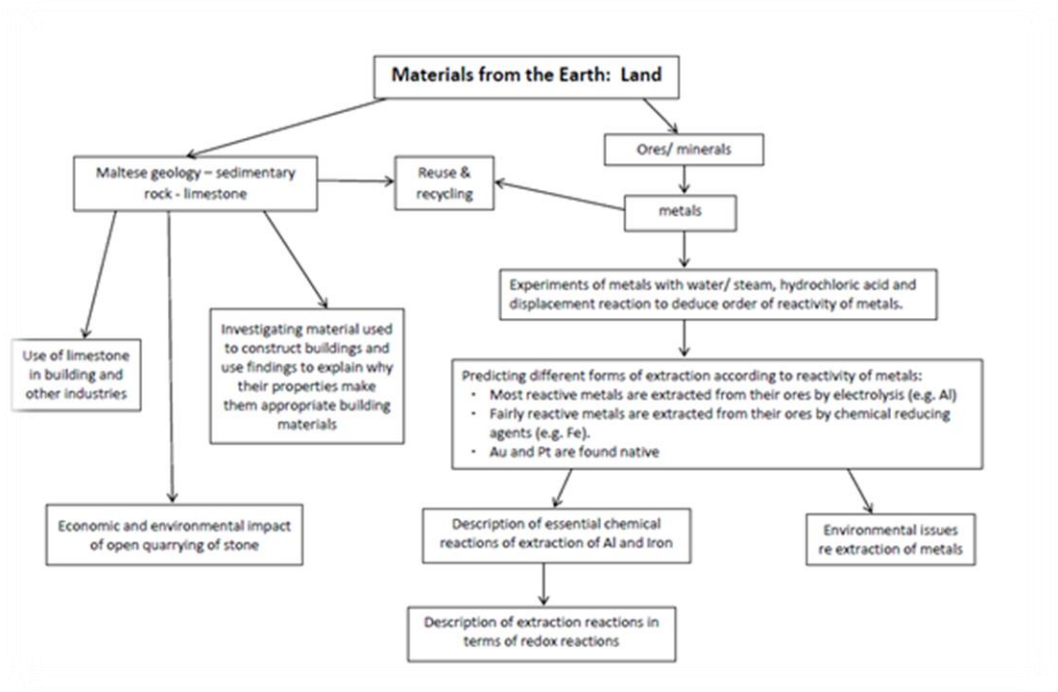

Fig. 2. Mind map showing ideas developed through the theme: Materials from the Earth – Land

2. Research questions

The main research questions behind this study were:

- What are teachers' views about the proposed programme?
- What challenges do they envisage?
- What support will teachers require for its implementation?

3. Methodology

A qualitative approach was selected in order to permit an in-depth study of the issues involved. Semi-structured interviews with open-ended questions were used to obtain information about the teachers and their views. An interview schedule provided background information about the teachers and their opinions about the current and proposed chemistry programmes. The interviews also sought to identify challenges envisaged in the implementation of the new programme and support the teachers would need for its implementation. Eight chemistry teachers were invited to participate in this study. They were chosen in such a way that teachers from the various categories were represented: male and female teachers from both state and non-state schools; teaching male and female students from both single sex as well as co-ed schools. Their age and teaching experience varied, in fact the range of teaching experience ranged from three to 20 years teaching chemistry.The interviews were audio-recorded and transcripts were prepared soon after the interviews. Thematic analysis of the transcripts provided an insight to teachers' views in relation to the research questions.

4. Results

4.1 Teachers' views of the strengths of the new programme

The teachers appreciated the fact that the new programme:

- introduces chemical ideas in a context, focusing on abstract ideas at a later stage;
- uses a thematic approach that is related to everyday life experiences;
- promotes the use of learner-centred pedagogies;

- includes specific and detailed LOs, clearly stating what students should be able to do at the end of a topic;
- involves LOs targeting lower and higher order cognitive skills together with other skills like doing presentations and conducting research;
- facilitates the use of assessment for learning strategies where LOs can be used by students to monitor their learning progress;
- is suitable for all students. Low achievers are better supported.

4.2 Limitations and challenges envisaged

Three important themes emerged as major challenges envisaged by teachers as shown in Table 1.

Table 1. Challenges envisaged by teachers

Time needed	• to teach the new programme using different pedagogies • for teachers to study, understand, assimilate and reflect on its application in the classroom • for teachers to revise and prepare new resources, lesson plans in advance
Assessment concerns	• how will the levels be used for assessment purposes? • how will teachers assess the LO? • how will students' progress be reported? • how will coursework be assessed? • how will summative assessment change to reflect the philosophy of the LOF?
Shift in culture required	• for teachers to change from teacher to learner-centred pedagogies • for students' to make decisions and gain ownership of their own learning • for parents

While generally in favour of starting with a context, some teachers thought that some fundamental concepts like kinetic theory, atomic structure, valencies and equations should be taught separately at an earlier stage before tackling other ideas. Other teachers found it difficult to accept the new arrangement of content in a non-traditional way such as the way ionic bonding and covalent bonding are placed in different themes rather than tackled together in a single topic specifically about bonding. This seems to show that although teachers welcome change, they too find it difficult to conceptualize organizing ideas and teaching chemistry in a way which is different from the way they have always experienced the subject.Time factors and and assessment-related matters were clearly major challenges. It is very clear that teachers were not finding enough information related to assessment in the document describing the programme. Coming from a very examination-oriented system and unsure whether the current examination system will remain in place, they were trying to see how the changes in the programme would be reflected in the method of assessment. The LOF requires a shift in culture for teachers, students and parents. According to the participants, teaching mixed ability groups of students especially in certain school contexts, remains one of the main challenges in the current system.

4.3 Support

The interviewees made a number of suggestions related to the support they would require. This included:

- ongoing training rather than one-off workshops to help shift teachers' thinking and pedagogy;
- availability of exemplars and lesson plans;
- discussions regarding sequencing of topics, the use of different pedagogies and assessment procedures and the implementation of the LOF with mixed ability groupings;
- formation of networks to discuss, share resources, ideas and good practice;
- use of the existing good support system of their department.

5.Conclusion

Teachers regarded the change as an improvement that is an opportunity to shift the focus on to students' learning, make the subject less abstract and more relevant. Yet there were many concerns about how this will be implemented in particular school settings and about whether the new programme will have to fit in the current timeframe and assessment system centred around high stakes examinations. It is important that assessment policies support the proposed changes. It is imperative that teachers are given the required support and that other policies are aligned to increase the likelihood of implementation

References

[1] Matriculation and Secondary Education Certificate Examinations Board 'SEC syllabus Chemistry 2016' Msida, University of Malta, Available at https://www.um.edu.mt/matsec/syllabus/sec_2016
[2] Pace, P. 'The State of Science Education in Malta'. Malta, The Malta Council for Science & Technology, 2000.
[3] Holbrook, J. 'Making Chemistry Teaching Relevant' Chemical Education International, 2006, 6 (1) available at www.iupac.org/publications/cei.
[4] Ministry of Education and Employment. 'A National Curriculum Framework for All'. Floriana, 2012. Available at http://education.gov.mt/en/resources/Pages/Policy-Documentation.aspx
[5] Learning Outcomes framework for the new programmes, 2015. Available at http://www.schoolslearningoutcomes.edu.mt/en/
[6] Ministry of Education, Employment and the Family (MEEF) 'Vision for Science Education, Consultation document'. Floriana, Government of Malta 2011.
[7] National Research Council (Center for Science, Mathematics, and Engineering Education). 'National Science Education Standards', Washington, DC,National Academies Press, 1996,103–207.
[8] Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. & Hemme, V. 'Science Education now: A renewed Pedagogy for the Future of Europe', Brussels, European Commission, 2007.
[9] American Chemical Society Committee on Education 'ACS Guidelines and Recommendations for the Teaching of High School Chemistry', 2012.
[10] Talanquer, V. 'Chemistry Education: Ten Facets to Shape Us', Journal of Chemical Education, 2013, 90 (7), 832–838.