Forms of Learning in Senior Secondary Science as Represented Through an Integrated Curriculum

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Introduction

This chapter considers the forms of learning in science that are represented in an integrated approach to the curriculum in the final year of schooling in Hong Kong. An integrated approach to the curriculum has been advocated by a number of curriculum scholars (e.g., Beane 1995, 1997; Hargreaves et al. 2001) as it is seen to be beneficial for student learning, by making learning applicable, meaningful for students, relevant and thus more motivating. In some countries there have been attempts to integrate science with mathematics (Berlin and Lee 2005) and/or other learning areas such as technology (American Association for the Advancement of Science 1993, 1998; National Science Teacher Association 1997). In Hong Kong, a new core subject called Liberal Studies (LS), introduced at the senior secondary level (age 15–17) in 2009, integrates multiple discipline areas including science. The subject is intended to provide opportunities for students to do "cross-disciplinary studies, pertaining in particular to critical thinking, life education, values education and civic education, with due consideration given to their relevance in the Hong Kong context" (CDC/HKEAA 2007, p. 2). As such, it provides an important example of quite different forms of intended student learning at a level of schooling where the genuine complexities of real situations and contexts and phenomena can be explored, including, obviously, quite different forms of science-related learning.

In this subject, Liberal Studies, learning and teaching take on a thematic or issue-based approach with each of its six modules based on a specific theme. Of the six modules, two have a science focus: Public Health and Energy Technology and the Environment. Both are grouped under an area named 'Science, Technology and the Environment'. The LS curriculum intends to be situated towards the 'more integrated' end of the curriculum continuum proposed by Fogarty (1991). The

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integration involves multiple subject disciplines such as social science, citizenship education, geography, personal or self-development, science, technology and public health. Disciplinary-based knowledge is almost unidentifiable in curriculum documents, and subject boundaries are non-existent.

Based on an intention to promote citizenship education, the design of the LS curriculum is consistent with Beane's (1995) suggestion that students be engaged in a search for "self and social meaning", and the curriculum focus on "problems, issues and concerns" (p. 616). According to Venville et al. (2008), the integration of different subject domains in a curriculum should "encompass a holistic view of knowledge…disciplines, including science, …[should] be considered a source of explanation and inquiry to answer and explore real life issues relevant to learners" (p. 860). With this, disciplines including science are seen to be important and contribute to a holistic view of knowledge. However, given the fact that (a) the LS curriculum is written with a thematic approach, with disciplinary-based content kept to a minimum or even non-existent, and (b) LS is taught by teachers regardless of whether they have a science background, it is doubtful whether "a holistic view of knowledge" is in fact maintained. It is likely that science content or science disciplinary-based knowledge can be considered when answering real life issues or themes being examined in the curriculum. However, without a science background, teachers will likely avoid or have no choice but to ignore scientific perspectives in the discussion. The subsequent discussion can hardly be expected to lead to balanced views or generate holistic understanding.

At the senior secondary level in Hong Kong, students are currently required to take four core subjects: Chinese, English, Mathematics and LS. In addition, they may take one to three elective subjects although it is common to have students taking two. With the limited number of elective subjects, it is possible for students to avoid taking any science subjects, and even if they take two elective subjects in the science domain, it is unlikely that they will cover all three main areas, namely physics, chemistry and biology, as was the case in the former Hong Kong Advanced Level Examination.

As LS is a core subject that has to be taken by all senior secondary level students in Hong Kong, it provides an excellent opportunity for all students to establish fundamental understandings of science. This chapter aims to portray the different forms of science learning that are represented in an integrated curriculum, and provides comments and suggestions for enhancing such a curriculum.

This chapter sets out to analyse the forms of learning in science that are represented in LS as an integrated curriculum, and does so by considering the following questions:

- what is the nature of science knowledge learned through this subject?
- what purposes are served by the science content, for the students and for the society in which the students live?
- when such a subject is presented as the integration of different or totally separate subject areas, is the resultant science learning coherent such that students' science understanding is built up and accumulated?

The Context

The Hong Kong senior secondary school education system has undergone a structural change that began in 2009. Instead of 5 years of secondary plus 2 years of senior secondary education, a 6-year secondary school structure was adopted. The last 3 years of secondary school are now named the New Senior Secondary (NSS). The NSS curriculum was implemented to provide students with a flexible, coherent and diversified learning experience (CDC/HKEAA 2007). LS is a new core subject[1] in the framework of the NSS curriculum that was developed based on the student-centered learning approach, and that employs inquiry learning as its approach to teaching and learning.

At the primary level in the current structure in Hong Kong, science is learned through a General Studies curriculum integrating six domains of study (Healthy living, People and environment, Science and technology in daily life, Community and citizenship, National identity and Chinese culture, Global understanding and the Information age) (Curriculum Development Council 2011). At the junior secondary level, this integration is built on the three domains of science, namely physics, chemistry and biology. At the senior secondary level, there is a choice of taking science as elective subjects. Alternatively, science and environmental studies topics are covered in the curriculum of the new core subject Liberal Studies, which in itself is also an integrated curriculum. The focus of this chapter is on the final years of the senior secondary level when Liberal Studies is taken as a compulsory core subject.

The Liberal Studies Curriculum

The emphasis of the LS curriculum is different from that of other subjects set for public examination at the Senior Secondary level. The emphasis is not on subject content but on the development of thinking skills, citizenship education and a positive attitude towards life. This section aims to provide some background about the subject and will introduce its aims, the evolution of its development, and the preparation for implementing the subject before it was launched in 2009.

The Curriculum Aims for Liberal Studies

The curriculum aims for the LS subject as provided in the 2007 curriculum document are as follows:

[1]LS was one of the elective subjects at the Advanced Supplementary (AS) level in the secondary curriculum before the NSS. The curriculum for AS level LS is different from the newly proposed LS in NSS.

(a) to enhance students' understanding of themselves, their society, their nation, the human world and the physical environment;
(b) to enable students to develop multiple perspectives on perennial and contemporary issues in different contexts (e.g., cultural, social, economic, political and technological contexts);
(c) to help students become independent thinkers so that they can construct knowledge appropriate to changing personal and social circumstances;
(d) to develop in students a range of skills for life-long learning, including critical thinking, creative problem solving, communication, and information technology skills;
(e) to help students appreciate and respect diversity in cultures in a pluralistic society and handle conflicting values; and
(f) to help students develop positive values and attitudes towards life, so that they can become informed and responsible citizens of society, the country and the world. (CDC/HKEAA 2007, p. 5)

Unlike other NSS level subjects, the emphasis is not on facts, concepts or skills specific to certain academic disciplines, e.g., mathematical skills. The curriculum document becomes a resource providing a framework for teachers to select content which allows issue-based inquiry and is consistent with a cross-curricular focus. The issues selected will be controversial so as to promote thinking from multiple perspectives, thus enhancing the development of critical thinking skills.

The curriculum consists of three areas of study, with modules under each area as follows:

Area: Self and personal development

Module 1: Personal development and interpersonal relationships

Area: Society and Culture

Module 2: Hong Kong today
Module 3: Modern China
Module 4: Globalization

Area: Science, technology and the environment

Module 5: Public health
Module 6: Energy, technology and the environment

The Development of the Subject and Its Evolving Purposes

LS was first introduced in 1991 as an elective subject at the Advanced Supplementary (AS) Level (F[Form or Grade].6 and F.7, aged 18–19) in the old curriculum. Since 1984, secondary school subjects in Hong Kong have had a greater focus on the local context and on political issues. This innovation was due to the anticipated change of sovereignty in 1997. The introduction of Liberal Studies was also related to a number of changes in curriculum directions from the 1970s to the 1990s. These changes include the introduction of interdisciplinary or cross-curricular subjects to meet the political, social and diverse education needs of pupils in Hong Kong in the 1970s. The introduction of cross-curricular subjects is consistent with the international literature on curriculum integration (Beane 1997; Drake 1998; Jacobs 1989, 1997). These researchers advocate cross-curricular subjects, arguing that they facilitate students' holistic understanding as reflected in real life contexts instead of compartmentalisation or separation of knowledge into academic subjects. Moreover, cross-curricular subjects provide opportunities for teacher and student collaboration while facilitating students' learning through making connections. In the 1990s, there were cross-curricular subjects to introduce civic education, moral education, sex education, and environmental education (Morris and Chan 1997a, b). The LS subject was introduced to provide students with opportunities to examine contemporary issues of social and personal significance from multiple perspectives, and to develop problem solving and critical thinking skills (Curriculum Development Council [CDC] 2000).

The introduction of LS in the 1990s was seen as an attempt to strengthen citizenship education with the resumption of sovereignty by the PRC in 1997 (Fok 1997). Fung and Yip (2010) interpret the introduction of the module 'Modern China' in LS as an attempt to develop a sense of citizenship, and compared this with the Basic Education Curriculum (Makabayan) in the Philippines with an emphasis on patriotic values.

The subject did not relate to any traditional school subject, nor was it a required subject for entrance to university disciplines. There was a lack of understanding among students about LS as a subject unlike traditional subjects such as Biology, Chemistry, etc. The subject was not very popular among AS level students. By 1996–1997, only 10 % of schools had adopted LS. Now that it is a compulsory subject for NSS students, there has of course been a significant increase in the number of students taking it since 2009.

The fundamental characteristics of the LS subject at the AS and NSS level were similar. It is a subject that aims to overcome the boundaries of traditional advanced-level academic subjects. Instead of focusing on abstract decontextualised knowledge at pre-university level, it challenges students to examine a wide range of real issues related to their everyday experiences. The theme of nurturing students to develop their critical thinking ability is maintained as the subject becomes compulsory at the NSS. According to Morris and Chan (1997a), the development of students' critical thinking ability is related to a social reconstructionist ideology which also promotes social and political awareness.

Preparation for the Implementation of the Subject

Many teachers new to the subject would be expected to share the teaching workload incurred by the introduction of this new core subject, and these teachers would have to cope with new subject content and a new teaching approach. Despite the fact that the subject LS had been launched at the AS level, Leung (2010) maintains that teacher professional development is essential in informing teachers the differences between the AS and NSS level subjects. He suggests that teachers' understanding related to curriculum integration has to be enhanced, and discussions on obstacles and issues related to implementation are important. Although the Education Bureau has provided workshops, and teacher-training institutes have organized training programmes for those who were intending to teach LS before the implementation of the NSS curriculum, many teachers were still concerned about their inexperience in teaching the subject.

The LS curriculum has been developed to fulfill many educational purposes including nurturing critical thinking skills and citizenship education. It is a subject that involves three years of senior secondary level study and occupies at least one-sixth of the total curriculum time in NSS. While the LS curriculum, being a core subject, offers immense opportunities to provide all senior secondary students with an understanding of science, further analysis is needed in order to ascertain the quality of the science learning, for example, whether the learning coheres with previous science learning experiences, whether conceptual development is considered across years, and if science learning is integrated or applicable to everyday situations as intended.

Forms of Learning in Science

Despite the different ways in which science is represented in different curricular settings, it is important that students can make sense of their learning. Will a curriculum which introduces science as integrated with other subject domains, as LS does, make better sense to students? What is the role of science conceptual understanding in an integrated curriculum, or is it essential? On the issue of whether conceptual understanding is essential, Vosniadou et al. (2008) maintain that certain activities can occur without conceptual grounds. Building on this argument, Aufschnaiter and Rogge (2012) suggest that everyday functioning, for example, turning on a switch, does not require a coherent 'explanatory' framework such as explaining how an electric circuit functions. They propose three different conceptual qualities or levels based on a discussion of examples. The first level describes students who adopt an 'exploratory approach'. The students describe their observations or explore an experimental set-up without making reference to any conceptual framework. The second level is an 'intuitive rule-based approach' in which students predict events purposefully, demonstrating that they have a basic understanding of science rules even though they may not be referring to them explicitly. The third level is an 'explicit rule-based approach' whereby students apply scientific concepts or rules to generalise events or phenomena. With this framework, students may not need to draw on science conceptual understandings if the teaching is targeted only at lower levels of understanding. However, in order that students can apply scientific rules or for generalization, science conceptual understanding is essential.

Many researchers share the view that science teaching covers more than science concepts and principles; it should include science processes, the nature of science and the relevance or application of science in everyday situations (Lederman 2008; McComas 1998; Osborne et al. 2003). More recently, to allow efficient learning and teaching of issues about science, Duit et al. (2012) argue that students need to learn about science processes and views of the nature of science.

The Nature of Science (NOS) has been an objective in science education in the USA (American Association for the Advancement of Science 1990, 1993; Klopfer 1964; National Research Council 1996; National Science Teachers Association 1982) for almost 100 years (Central Association of Science and Mathematics Teachers 1907; Kimball 1967; Lederman 1992). Abd-El-Khalick (2005) provides an assessment of experts' understanding of the general notions of NOS appropriate at school which suggests that:

1. Science is a human enterprise, practiced within a community of scientists.
2. Scientists ask and answer questions about the natural world in an attempt to understand it.
3. Scientific knowledge is generated by a range of methods, often involving the creation of hypotheses, theories, laws and models. These have different but related roles.
4. Scientific knowledge demands evidence (is empirical), and is testable through rigorous processes.
5. Creativity, imagination and curiosity also play a key role in knowledge generation.
6. As a social activity, science is influenced by cultural, societal and personal factors, including economic and political considerations.
7. Scientific knowledge is provisional and developmental.

Moreover, Driver et al. (1996) provided five arguments that help us to understand the importance of understanding NOS:

1. to make sense of science and manage the technological objects and processes in everyday life;
2. for informed decision-making on scientific issues;
3. to appreciate the value of science as part of contemporary culture;
4. to help develop an understanding of the norms of the scientific community that embody moral commitments that are of general value to society; and
5. to facilitate the learning of science subject matter.

As for how NOS understanding may facilitate the learning of science, Bell et al. (2000) report that NOS understanding is necessary for critical thinking and problem solving, it provides a more authentic context for understanding scientific knowledge and its progression, and it is linked to scientific literacy. The understanding of NOS forms part of science learning and emphasizes the learning of science in relation to social and everyday contexts.

In discussing whether practical skills are essential for science learning, there are views that it is not only a 'mechanical' aspect (Gott and Duggan 1995); students may draw on practical experiences to predict, explain, and transfer to new contexts (Wellington 1998). Practical scientific inquiry is seen as a subset of practical work that demands the application of both scientific conceptual understanding and procedural understanding including design, measurement and evaluation of the inquiry (Gott and Duggan 1995). Toplis (2012) argues for a link between conceptual and procedural understanding of science. He draws on PISA (2006) data, suggesting that motivation and attitudes are relevant to science, and investigates the relationship between practical work and science learning attitudes. He calls for a reappraisal of scientific inquiry such that it achieves a number of learning outcomes, namely: enhancing conceptual understanding, development of inquiry skills, promoting student initiated inquiries, and encouraging group work and discussions among students.

Despite the fact that the learning of science is thus not confined to science conceptual understandings, science conceptual understandings are still essential for more advanced levels of learning in which students need to apply scientific rules and/or make generalizations. Science inquiry, NOS and science processes are taken as different forms of science learning. The learning of NOS has to take place with reference to social or everyday contexts.

Forms of Science Learning in the Liberal Studies Curriculum

This chapter analyses the nature of science knowledge learned through the LS curriculum: the purposes of the science content for the students and for the society in which the students live; and, as LS is presented as the integration of multiple disciplinary or subject areas, whether the resultant science learning is coherent such that students' science understanding is built up and accumulated. To answer these questions, the curriculum document (CDC/HKEAA 2007) and the Hong Kong Curriculum Development Council (CDC 2012) teachers' manual were analysed. The latter provides teaching materials and suggestions addressing science, technology and environment issues. These two documents thus form the sources of data to answer these questions.

Drawing on the two official curriculum documents mentioned above, the analysis provided in this chapter is at an 'institutional' level according to Deng (2009) who examines the curriculum content of liberal studies with the framework proposed by Doyle (1992a, b). The framework consists of three levels of curriculum structure—the institutional, the programmatic, and the classroom. He argues that a school subject is a socio-technical construct in the form of design (e.g., curriculum frameworks, syllabi, and textbooks). Being driven by curricular policy, the institutional curriculum is based on values and the demands of the society or country. The programmatic curriculum consists of a description of the content in the school subject, materials for use at the classroom level, and learning and teaching activities. The classroom curriculum comprises instructional events and connects with the experience, interests and the capacities of students (Westbury 2000).

The Nature of Science Knowledge and the Purpose of the Science Content Learned Through This Subject

Starting from an institutional perspective, an examination of the official curriculum document suggests that it has explained linkages among the three areas of study in the subject, namely, self and personal development; society and culture; and science, technology and environment. While these are presented as areas of study, they are not found as separate school subjects at lower levels of education. The relationship between science, technology and environment with the other two areas is explained as follows:

> Self & Personal Development < > Science, Technology & the Environment
> Knowledge in science and technology helps individuals to understand many problems that they encounter, so that they can make informed decisions and appreciate their responsibilities to society, to the world and to the environment. On the one hand, the development of science and technology facilitates human exploration of the material world, and improves our lives. On the other, it affects our way of life, our mode of communication and even our ways of thinking. To make better use of science and technology in our lives has become a critical modern concern.
>
> Society & Culture < > Science, Technology & the Environment
> The development of science and technology has helped to hasten social development, reduced the distance between regions, and brought a new impulse to cultural encounters and growth. For today's society, sustainable development requires a simultaneous consideration of factors related to science, technology and the environment. Given that social problems have become increasingly complex, the progress of science and technology needs to catch up with the speed of change in society—but any new technology will also *bring new challenges and problems to society and the environment*. (CDC/HKEAA 2007, p. 12, emphasis added)

From the above descriptions, the purpose of the science content is explicit. Students need to 'make informed decisions', understand how 'to make use of science and technology in our lives' and how science and technology 'bring new challenges and problems to society and the environment'. In terms of science knowledge, these understandings will involve the adoption of an 'explanatory framework' (Aufschnaiter and Rogge 2012) within which the students do not necessarily need to make reference to any conceptual framework, or if so, a minimal understanding or an 'intuitive rule-based approach' will be sufficient.

The curriculum document also provides 'key questions for enquiry' for the two STE modules (Public health and Energy, technology and the environment) in the area of science, technology and environment. These questions are presented in Table 1.

Within each module, there are two themes. In the module 'Public health', theme 1 is 'Understanding of public health', and theme 2 is 'Science, technology and public health'. In the module 'Energy, technology and the environment, theme 1 is 'Influences of technology', and theme 2 is the 'Environment and sustainable development'. Under each theme, the curriculum document provides a few questions for enquiry and some explanatory notes. A summary of the questions for enquiry is provided in Table 2.

Table 1 Key questions for enquiry in the area of study: science, technology and the environment (CDC/HKEAA 2007, p. 15)

Public health	
Understanding of public health	How is people's understanding of disease and public health affected by different factors?
Science, technology and public health	To what extent does science and technology enhance the development of public health?
Energy, technology and the environment	
The influences of energy technology	How do energy, technology and environmental problems relate to each other?
The environment and sustainable development	Why has sustainable development become an important contemporary issue? What is the relationship between its occurrence and the development of science and technology?

Table 2 Questions for enquiry in the modules 'public health' and 'energy, technology and the environment'

Public health
How is people's understanding of disease and public health affected by different factors?
How did people understand the causes of disease in the past? *Was their understanding scientific?*
How is people's understanding of health affected by economic, social and other factors?
How is people's understanding of public health affected by the development of science and technology?
In what ways is people's understanding of public health affected by health information, social expectations, personal values and beliefs in different cultures?
To what extent does science and technology enhance the development of public health?
Can science and technology provide new solutions in the prevention and control of diseases?
In the area of public health, how is the development of science and technology affected by various factors, and what issues are triggered by this development? *How can the fruits of scientific and technological research be respected and protected?*
What challenges do different sectors of society, the government and international organizations have in maintaining and promoting public health?
Energy, technology and the environment
How do energy technology and environmental problems relate to each other?
How does the development of energy technology affect the exploitation and use of energy?
To what extent does the development of energy technology create or solve environmental problems?
What are the implications of environmental change on the development of energy technology?
How do energy problems affect international relationships, and the development of countries and societies?
Why has sustainable development become an important contemporary issue? What is the relationship between its occurrence and the development of science and technology?
How do science and technology match with sustainable development? What are the constraints?
How do the living styles of people and social development affect the environment and the use of energy?
What responses could be made by the public, different sectors, and governments regarding the future of sustainable development?

CDC/HKEAA (2007), pp. 47–55—emphasis added

In considering whether the understanding is scientific, students will certainly need to have some understanding of science concepts and the views of the nature of science. For the other question about ‘the development of science and technology’, students will need to learn about the history of science. For many of the questions, students need to analyse and work out the relationship between science and other dimensions of understanding, such as the cultural, social and economic perspectives. As a result, the demand on students is beyond a basic understanding of scientific concepts; it requires students to assimilate, apply and integrate their understanding from cultural, social and economic perspectives.

The questions ‘Can science and technology provide new solutions in the prevention and control of diseases?’ and ‘How does the development of energy technology affect the exploitation and use of energy?’ require students to apply an ‘intuitive rule-based approach’ (Aufschnaiter and Rogge 2012). The application of updated scientific understanding is needed if substantive answers are to be provided. If not, for students with superficial scientific understandings, they may not be able to judge if the so-called ‘new solutions’ or ‘development’ are in fact novel or if such solutions or developments are effective, and hence be unable to make ‘informed decisions’, as expected by the curriculum developers. Similarly, in answering the questions ‘What are the implications of environmental change on the development of energy technology?’ and ‘How do science and technology match with sustainable development? What are the constraints?’ substantive answers will require an ‘intuitive rule-based approach’ (Aufschnaiter and Rogge 2012).

In answering the question ‘How can the fruits of scientific and technological research be respected and protected?’ some understanding of the nature of science is again essential. Students will need to understand how scientific discoveries are shared among researchers as well as with other members of the society. For the question ‘How do the living styles of people and social development affect the environment and the use of energy?’ students will need to be able to apply their scientific understanding to everyday situations or, as Abd-El-Khalick (2005) puts it, to make sense of science and manage the technological objects and processes in everyday life.

The LS curriculum demands that students apply an ‘intuitive rule-based approach’ (Aufschnaiter and Rogge 2012) at the minimum. They need to develop a good understanding of scientific concepts, views of the Nature of Science and the History of Science and further apply such understanding in everyday life situations. Further, they need to relate, if not integrate, science understandings with social, cultural and economic perspectives.

If the learning of practical skills and practical scientific inquiry are seen as essential components of science learning, then LS does not offer students learning opportunities to develop these skills. The issue-based approach is built around the discussion of contemporary social issues, in this case, ones that are related to science, technology and the environment. There is no explicit requirement in the LS curriculum for practical science activities, nor does it remind teachers to provide students with opportunities for practical scientific inquiry.

Coherence and Accumulation of Science Learning

In an attempt to answer the question of how and whether the resultant science learning is coherent such that students' science understanding is built up and accumulated as a result of studying Liberal Studies, detail is drawn from both the teachers' manual published by the Curriculum Development Institute (CDC 2012) and the curriculum guide (CDC/HKEAA 2007). Science learning is defined to include knowledge or content, the method of inquiry, as well as views of the nature of science.

First, some background information or basic understanding may serve as a basis for students to build up their scientific understanding. For example, understanding of concepts or understandings such as 'what are food additives', 'types of food additives', and 'the functions of food additives' may be further developed, building on basic understanding, as students study LS.

Second, the inquiry method as advocated by the LS curriculum may be used to gain further understanding of the science concepts. For example, the teachers' manual states that teachers should "engage students in information collection to enhance their understanding related to the topic" (CDC 2012, p. 94).

Third, science understanding is established in LS with reference to its application to life in modern society; basic understanding may support the students in further explorations. For example, the use and impact of renewable and non-renewable energy is an on-going debate, and whether the use of new sources of energy may reduce pollution and the related social concerns (CDC 2012, p. 96) can be further explored when students possess initial understandings. As suggested by the teachers' manual, during the process of inquiry, students are expected to:

- build on personal experience to reflect on personal lifestyles in assessing the impact on the environment;
- adopt different roles such as personal, retailers, environmental protection agencies, government, plastic manufacturers, etc. to understand the debate of plastic bag tax;
- work out ways to balance the quality of personal lifestyle, economy, social development and protecting the environment;
- analyse present and past situations and work out possible solutions;
- evaluate the effectiveness of the plastic bag tax and prepare for the future. (CDC 2012, p. 94)

These processes are related to the study of the nature of science. Students' understanding of science and technological objects may explain processes in everyday life, inform their decision-making, and help them appreciate the value of science in society and culture, while the implications of scientific advancement for moral commitments are to be accumulated and built up through their study of these two modules.

Conclusion

The analysis of the LS curriculum guide and the related teachers' manual presented above suggests that students are likely to apply an 'exploratory approach' or 'intuitive-based approach' in order to inform their decision-making as citizens. However, in order to provide comprehensive answers to questions related to the impact of new advancements in science and technology, students will need to apply an 'explicit rule-based approach'. As for the purpose of science learning, scientific understanding is to help students to 'make informed decisions' and understand how 'to make use of science and technology in our lives' and how science and technology 'bring new challenges and problems to society and the environment'. Further, students are required to work out the relationship between science and other dimensions of understanding, such as the cultural, social and economic perspectives. However, the LS curriculum does not offer opportunities to develop either science process skills or practical skills.

As for whether students' understanding is coherent and accumulated, continual effort will be needed by students to apply the methods of inquiry they learn from the subject. In order to address questions related to the impact of scientific advancement as listed in the curriculum, sound understanding of the nature of science is crucial. In order to meet these demands of the curriculum, either students have to start their LS in Secondary 4 with a relatively strong science background, or the LS curriculum needs to provide time and opportunities for them to enhance their science learning. For example, students need to have experience with scientific inquiry projects, and to have learned about the Nature of Science and/or the History of Science. This latter suggestion, to enhance the science component in the curriculum, would require revisions of the aims and content of the LS curriculum would need to be put forward.

In recent attempts to review the New Senior Secondary Subjects, initiated by the government, there were suggestions to make the LS curriculum less challenging for both the students and teachers, with proposals to reduce the curriculum content. This could involve a reduction in the content of each module or a reduction in the number of modules. For example, suggestions include the deletion of both modules related to science or the integration of the content of these two modules into the rest of the curriculum. It is suggested that the assessment component, which takes the form of student-led inquiry (Independent Enquiry Studies, IES), be revised to involve a secondary analysis of information or data or a documentary analysis. These suggestions confirm a perception among teachers that the curriculum is overcrowded. As teachers without a science background will be teaching the subject, it is not surprising to see the suggestion of deleting or integrating the two science modules. Student workload is seen to be heavy and hence teachers urge clarification that in the IES component, the collection of first-hand data is not required.

If the suggestion of deleting the science modules is accepted, science educators will likely regard this development as a loss of a good opportunity to integrate science learning with other subject domains, making it meaningful and accessible to all senior secondary students. In considering revisions of the curriculum, I strongly recommend a holistic consideration of students' science learning experience. Curriculum developers should consider different forms of science learning, i.e., understanding of scientific concepts, scientific inquiry, nature of science and history of science. At the same time, the current emphasis on integration and application in everyday situations, as well as with cultural, social and economic perspectives, is retained.

In addition to considering ways to enhance the curriculum content to strengthen students' science learning, curriculum developers should seriously consider teachers' understanding of science. The science education literature suggests that teachers retain their subject-specific responsibility and tend to focus on science discipline-based knowledge. Attempts at integration, providing opportunities for application or adopting a holistic view of knowledge, need to be encouraged (Lear 1993; Venville et al. 2008). The LS curriculum is situated near an extreme end of the curriculum integration continuum proposed by Fogarty (1991), where science disciplinary-based knowledge is almost non-existent. The revision of the curriculum will need to address the balance between both ends of the continuum. In addition, learning and teaching can be designed to be beneficial from both a disciplinary-based perspective and an integrated perspective of the curriculum.

The next issue to be investigated would be the relationship between teachers' understanding of the LS subject and whether and how this influences student learning. As the subject is in its early years of implementation, there is still much discomfort among teachers in teaching the subject. Wilson and Kittleson (2012) propose developing a theoretical framework to describe and explain teacher discomfort. In fact, Frykholm (2004) describes 'debilitating' and 'educative' discomfort for teachers. The former relates to teachers who are concerned about the appropriateness of the curriculum and the adequateness of their own conceptual understanding to implement the curriculum reform. The latter refers to teachers who are able to "tolerate discomfort" and use it as a "pedagogical tool" (p. 146). Moreover, differences in pedagogical methods in teaching a discipline-based subject and an interdisciplinary subject need to be considered by curriculum developers.

Beyer and Davis (2009) call for an investigation into Pedagogical Content Knowledge (PCK) for science teachers and their curricular planning decisions in analysing the adoption of curriculum reform initiatives. In fact, the two science modules in the LS curriculum would be best taught by science teachers as they are more aware of enhancing students' science learning. It may be too much to require that teachers without science backgrounds achieve the integration and application of science understanding in social, cultural and economic perspectives. This tension is evident in the suggestions to delete the two science modules in the recent curriculum review.

Critics have also raised issues related to high-stakes assessment and the subject being assessed in a public examination. Educators and teachers have warned that this move would deter teacher professional freedom, instructional imagination and creativity (Luke et al. 2008). Although the aims and the learning outcomes for students are explicit in the curriculum document and teachers' manual, the impact of public examination on the achievement of the planned learning outcomes remains to be seen. Finally, the analysis in this chapter is based on an 'institutional' curriculum plan (Doyle 1992a, b); study at the 'programmatic' and 'classroom' levels will provide further information on whether the different forms of student learning have in reality taken place.

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