Learning from Hong Kong Biology Olympiad for Secondary Schools 2012/2013: Strengthening the Learning of Curriculum Emphases

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Abstract

Learning nature of science (NOS), scientific inquiry (SI) and the inter-connections between science, technology, society and environment (STSE) have long been viewed as major components of scientific literacy, and as important learning outcomes of the science curricula in many countries. Following the international trend, Hong Kong has incorporated these three emphases in the New Senior Secondary Science curricula since 2009. In regard to this, the Hong Kong Biology Olympiad for Secondary Schools 2012/2013 - a localized assessment - was organized to understand how students perform in these areas after the implementation. A total of 1376 students from 275 local secondary schools participated in the exercise. Results show that students performed poorly in NOS questions (mean= 3.26 out of 15 marks) and SI questions (mean = 5.10), when compared with the inter-connections between STSE (mean = 9.44) and the subject content knowledge (mean = 7.64). Further analysis suggests that there is a moderate correlation between the average scores of subject content knowledge and the inter-connections between STSE. The rationale of designing the assessment, sample questions and the implication of the study to Hong Kong science education will be discussed.

Introduction

Scientific literacy for a responsible citizenship always stands out as the primary goal of science education (Agin, 1974; Abd-El-Khalick, 2003). It is advocated by

different national curriculum documents in many countries and regions till nowadays (e.g. American Association for the Advancement of Science [AAAS], 1990, 1993; Curriculum Development Council & Hong Kong Examinations and Assessment Authority [CDC & HKEAA], 2007b, 2007c, 2007d, 2007e, 2007f; National Research Council [NRC], 1996; Millar & Osborne, 1998). Although the definition of scientific literacy is controversial with little consensus (Shamos, 1995; DeBoer, 2000), various documents depict some common key components. One of these, as highlighted by Durant (1993), is that "…stands for what the general public ought to know about science" (p.129). In other words, students are expected to be engaged in science-related social issues in their every day life, so that they can make informed decisions when addressing those issues (Solomon, 1993; Aikenhead, 1994). Hodson (2006) further interpreted the meaning of scientific literacy into three dimensions: (1) learning of science, (2) learning to do science, and (3) learning about science. These three dimensions associate with what many science educators aim to teach: (1) content knowledge (learning of science), (2) scientific inquiry (learning to do science) and (3) nature of science (learning about science).

Biology Curriculum in Hong Kong

Echoed with the above-mentioned international trend, the Hong Kong Senior Secondary Biology Curriculum Guide has also explicitly declared in its aim:

> "The overarching aim of the Biology Curriculum is to provide biology-related learning experiences that enable students to develop scientific literacy, so that they can participate actively in our rapidly changing knowledge-based society, prepare for further studies or careers in the fields related to life science, and become lifelong learners in

science and technology"(CDC & HKEAA, 2007b, p. 3)

As shown in a diagrammatic representation of the curriculum framework (CDC & HKEAA, 2007, p. 10) in Figure 1, knowledge, skills, values and attitudes are highlighted on top of every content topic to be taught. In addition, across all these topics, scientific inquiry (SI), science-technology-society-environment connections (STSE) and nature of science (NOS) are the curriculum emphases for achieving the intended goal of fostering scientific literacy.

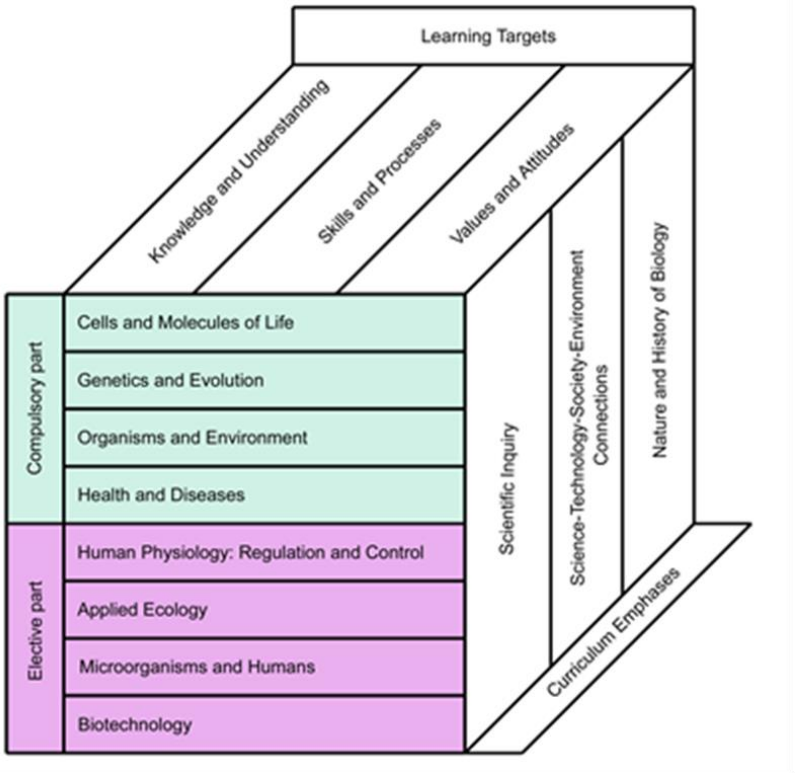


Figure 1 Diagrammatic Representation of the Biology Curriculum Framework (CDC & HKEAA, 2007, p. 10)

Hong Kong Biology Olympiad for Secondary Schools

In view of promoting these curriculum emphasis i.e. NOS, SI & STSE, the HKASME has organized Hong Kong Biology Olympiad (2012/13) and tried to study the related learning outcomes from the first cohort of New Senior Secondary Biology students. The competition is a 1-hour test with 60 multiple-choice questions which covers the common syllabuses shared by the HKDSE Biology and the HKDSE Combined Science (Biology). The questions are related to four areas in Biology with equal weight:

1. content knowledge (CK) (25%),
2. nature of science (NOS) (25%),
3. scientific inquiry (SI) (25%) and
4. science, technology, social & environment connection (STSE) (25%).

Each school could nominate at most 2 teams, each consisting of 5 students in maximum. After the enrollment, 275 local secondary schools with 1376 students of Grade 10-12 participated. Table 1 illustrated the general performance of students in the four areas as well as in the overall paper. The performances in CK and STSE are better among the four areas. On the other hand, the results of NOS and SI are much disappointing. Further analysis suggests that there is a moderate correlation between the average scores of content knowledge and the inter-connections between STSE. No other significant correlation was found between other combinations of results from other parts.

Scopes	Mean Mark	Full Mark
Content Knowledge (CK)	7.64	15
Nature of Science (NOS)	3.26	15
Scientific Inquiry (SI)	5.10	15
Science-Technology-Society-Environment (STSE)	9.44	15
Whole Paper	25.44	60

Table 1: The General Performance in the Four Areas and in the Overall Paper

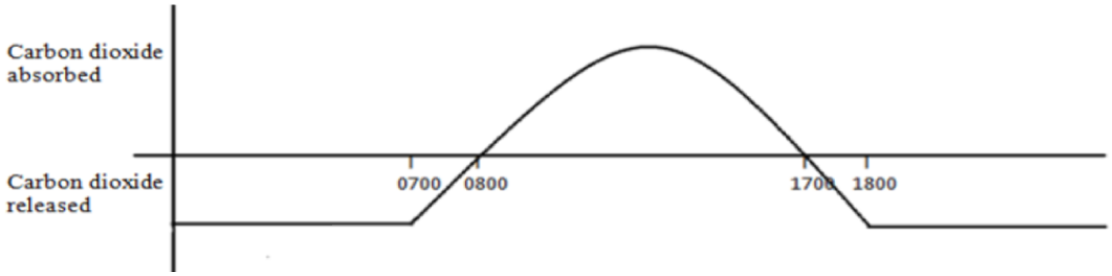
Evaluations on students' performance

In order to make a closer look on the performances of students and their problems encountered, some selected questions are analyzed and discussed in the following section.

Content Knowledge (CK)

Generally, students performed quite well in this scope. Below shows one typical questions with the corresponding response percentage.

Q13 The following diagram shows the carbon dioxide absorbed and released during a day by a plant:



When does the plant have a net gain of dry mass during the day?

A. at 1300 only B. 0700 – 1800

C. 0800 – 1700 D. 1800 – 0700

Correct Answer: C

Option	No. of students	Percentage
A	54	4%
B	120	9%
C	***1150***	***84%***
D	51	4%

In Q13, most of the students (84%) could obtain a correct answer. Yet, in certain questions requiring the application of concepts, students were unable to respond correctly. The following question is one of the examples.

Q1 Membrane proteins are necessary for many nerve functions. Which process in nerves does **not** require a membrane protein?

A. Diffusion of neurotransmitter
B. Binding of neurotransmitter
C. Active transport of sodium ions
D. Propagation of a nerve impulse

Correct Answer: A

Option	No. of students	Percentage
A	***520***	***38%***
B	181	13%
C	163	12%
D	511	37%

Only 38% of students answered the question (Q1) correctly. Most of them seem to have a limited knowledge about the concepts of diffusion, active transport and osmosis, as required by curriculum. However, they cannot explore on their own to further explain the concepts in a new context, e.g. the membrane transport in living organisms, on top of curriculum requirements.

By comparing these two and other questions, the possible reason for such discrepancy in performances may be caused by the examination-driven education system in Hong Kong. Students tend to focus on what to be assessed in the public examination and so, a rote learning style rather than a deep learning approach is generally employed.

Nature of Science (NOS)

As mentioned before, the performances in NOS were not satisfactory. Below are the questions related to this area.

Q24 Scientists cannot single out an explanation for the origin of life. The most possible reason is that

A. the origin occurred long time ago.
B. it is difficult to carry out experiments to prove it.
C. no evidence can be found to validate the origin.
D. the origin no longer exists.

Correct Answer: C

Option	No. of students	Percentage
A	89	6%
B	538	39%
C	***701***	***51%***
D	48	3%

In the above question (Q24), only 51% of students can identify that the availability of evidence is the reason. 39% of students just simply linked to the experimentation. This obviously reflects that one misconception held by the students - experimentation is a must to build up scientific knowledge. They miss a concept that scientific knowledge can be also constructed based on previous evidences. Another question (Q23) shown below also demonstrated this similar problem.

Q23 The use of fossil record to study evolution involves

(1) creativity
(2) evidence-based interpretation
(3) experimentation

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Correct Answer: A

Option	No. of students	Percentage
A	***315***	***23%***
B	19	1%
C	784	57%
D	257	19%

Once again, many students (77%) believed that experimentation should be involved in studying scientific concepts (Q23). On the other hand, only 23% of students could point out creativity, as one of crucial components of NOS, should be involved. Such response supported the idea that our students were quite weak in certain aspects of NOS.

Scientific Inquiry (SI)

Like the case of NOS, the students were rather weak in SI. A sound and valid conclusion with reference to the existing evidences is important in SI. Nevertheless, from the below question (Q41), only 51% of students made a correct conclusion based on the given observation. Other students seem to recite similar but not precise ideas according to what they have learnt in the lessons or in the textbook. This question mirrors the fact that our students did not realize the construction of a conclusion though they have experienced the learning of conclusion in secondary school science.

Q41 The scientists removed the pancreas of a healthy dog, and it shows signs of diabetes. When they injected extracts of pancreas into the same dog, the signs of diabetes disappeared. What conclusion can be drawn from the above treatments?

A. A lack of the pancreatic extracts would lead to diabetes.
B. The secretion of the pancreas can reduce blood glucose level.
C. Insulin can convert glucose into glycogen in the liver and muscles.
D. Pancreas can detect the blood glucose level and regulate it.

Correct Answer: A

Option	No. of students	Percentage
A	***700***	***51%***
B	470	34%
C	41	3%
D	165	12%

Another idea of SI lacking is the causal relationship in explaining scientific phenomenon. Below is one of the relevant questions.

Q37 4 students (P, Q, R and S) are asked to compare and explain the average body temperatures of people living in Hong Kong and South Pole. Below are their responses:

P: The two body temperatures are very similar because both two groups need a suitable body temperature to facilitate enzymatic reactions in the body.

Q: The two body temperatures are very similar because human are homoeothermic.

R: The two body temperatures should differ for at least 5°C because the two regions have different climates.

S: The two body temperatures should differ for at least 5°C because the people in two regions have different clothing.

Which of the students points out the correct comparison and cause?

A. P

B. Q

C. R

D. S

Correct Answer : B

Option	No. of students	Percentage
A	679	49%
B	***614***	***45%***
C	73	5%
D	10	1%

Almost half of the students wrongly regarded the need as the cause. They could not distinguish between significance and cause. Thus, they misunderstood that same body temperature was caused by the need of enzymatic activity. In fact, they should identify the physiological cause to explain the biological phenomenon, i.e. a constant body temperature, in this question. This indicates that students hold limited understanding on the causal relationship in biology.

Science, Technology, Social & Environment connection (STSE)

The performance of students in STSE is the best among the four areas. Taking the following question (Q55) as an example, many students (63%) could give a correct answer when they were asked to explain the compositions in different cleaning agents. The reason can be linked to the great effort paid on STSE in the local curriculum during the previous decades. However, we shall note that still some students (37%) could not apply the concepts in daily life examples.

Q55 Both washing powder and body cleanser are cleaning products. However, their compositions are different, in which lipase is often added into the washing powder but not into the body cleanser. This is because lipase

A. is not so effective to help the removal of dirt on the body
B. can work best when mixed with other enzymes in the washing powder
C. may cause damage on the skin
D. is denatured in a hot bath

Correct Answer: C

Option	No. of students	Percentage
A	172	13%
B	78	6%
C	***866***	***63%***
D	255	19%

Reflections

From the overall statistics, the performances of students in STSE are better whereas those in NOS and SI are a bit disappointing. We come up with four possible reasons. First, STSE has been established for long and so much have been integrated into questions setting, which are relatively familiar to the students. Second, the local examination system seems to over-emphasize on solid knowledge. This undoubtedly

drives the students to fall into the mode of rote learning and focus the concepts written in the textbooks instead of mastering the application of scientific knowledge. Third, the exposure on SI is generally limited. Many practical stressed by the school-based assessment (SBA) in the public exam are done by the students. Yet, students seem like a machine which keeps doing practical but not realize the crucial meaning of SI behind. Lastly, lack of NOS questions reduces the corresponding assessment for learning. This has directly influenced the attention of students on this area.

As science teachers, we hope to attain different goals of science education, just like what is stated in the official curriculum documents. However, it appears still a long way to go with our students. From the recent report of Hong Kong Biology Olympiad, perhaps, it is time for us to rethink, reflect and reform what happens in teaching and learning.

References

Abd-El-Khalick, F. (2003). Socioscientific issues in pre-college science classrooms. In D. L. Zeidler (Eds), *The role of moral reasoning on socioscientific issues and discourses in science education* (pp. 41-61). Netherlands: Kluwer Academic Publishers.

Agin, M. L. (1974). Education for Scientific Literacy: A Conceptual Frame of Reference and Some Applications. *Science Education,* 58(3), 403-415.

Aikenhead, G. S. (1994). *What is STS science teaching. STS Education: International Perspectives in Reform*. New York: Teacher's College Press.

American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science (AAAS) (1993). *Benchmarks for scientific literacy*. Oxford: Oxford University Press.

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007b). *Science Key Learning Area: Biology – Curriculum and Assessment Guide (Secondary 4 – 6)*. Hong Kong: Education and Department.

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007c). *Science Key Learning Area: Chemistry – Curriculum and Assessment Guide (Secondary 4 – 6)*. Hong Kong: Education Department.

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007d). *Science Key Learning Area: Combined Science – Curriculum and Assessment Guide (Secondary 4 – 6)*. Hong Kong: Education Department.

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007e). *Science Key Learning Area: Integrated Science – Curriculum and Assessment Guide (Secondary 4 – 6)*. Hong Kong: Education Department.

Curriculum Development Council & Hong Kong Examinations and Assessment Authority (2007f). *Science Key Learning Area : Physics – Curriculum and Assessment Guide (Secondary 4 – 6)*. Hong Kong: Education Department.

DeBoer, G.. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37(6), 582-601.

Durant, J. R. (1993). What is scientific literacy? In J.R. Durant & J. Gregory (Eds.), *Science and culture in Europe* (pp.129-137). London: Science Museum.

Hodson, D. (2006). Why we should prioritize learning about science, *Canadian Journal of Science, Mathematics and Technology Education*, *6*(3), 293-311.

Millar, R., & Osborne, J. (Eds.) (1998). *Beyond 2000: Science education for the future*. London: King's College London.

National Research Council (NRC). (1996). *National science education standards. Washington*. DC: National Academy of Sciences.

Shamos, M. H. (1995). *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University Press.

Solomon, J. (1993). *Teaching Science, Technology & Society*. Philadelphia, CA: Open University Press.