Impacts of a STSE high school biology course on the scientific literacy of Hong Kong students

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Contents

Abstract

The PISA performance of Hong Kong has prompted this study to investigate if scientific literacy (SL) of Hong Kong students can be improved further through a high school biology course employing the STSE approach. A STSE course was developed in accordance to the contexts of Hong Kong and a framework for the assessment of scientific literacy was developed. Two classes of high school biology were selected for a quasi-experimental study: one taught with the STSE course and the other taught traditionally. Compared to the traditional class, the STSE approach produced better learning outcomes in: (i) application of scientific concepts, (ii) scientific inquiry skills, and (iii) STSE awareness, but showed no significant differences in recall of scientific concepts and attitudes toward science learning. The results show that a STSE approach of this study is feasible in an overtly exam-driven context of Hong Kong in light of its superiority in conceptual understanding over traditional teaching. But its impacts on NOS understanding and attitudes are found limited. The results have implications for science curriculum reforms in Hong Kong.

Keywords: scientific literacy; STSE education

Introduction

Hong Kong has consistently ranked among the top in scientific literacy as assessed by the Programme for International Student Assessment (PISA): third in 2000, 2003 and 2009, and second in 2006 where science was the major domain (HKPISA, 2011). Despite these seemingly remarkable performances, doubts are cast on the quality of the curriculum and instruction of science in Hong Kong. Studies found that science classrooms of Hong Kong were dominated by didactic, teacher-centered instruction (Tsang 2004), overemphasizing the acquisition of scientific knowledge over the development of scientific inquiry skills and understandings of the nature of science (NOS) (Cheung 2000). Students were seldom given opportunities to conduct open-ended, independent investigations, while most of the practical work were recipe-type and highly teacher-directed (Yip and Cheung 2004). These observations are consistent with the performances of

Hong Kong students in some areas of PISA: relatively good at explaining phenomena scientifically, which pertains more to scientific knowledge, but weak in identifying scientific issues, which is about scientific reasoning and understanding of NOS (HKPISA 2011).

The PISA results suggest that there is room for Hong Kong students to further improve their scientific literacy (SL) through shifting the emphasis of science instruction from scientific knowledge to scientific inquiry and nature of science. However, Hong Kong, as with most Asian communities, has an overly exam-oriented education system, in which preparing students for public examinations is the major goal of schooling (Tsang 2004; Tsui, 2008; Yip and Cheung 2004). Despite that recently public science examinations in Hong Kong have put greater weight on the assessment of scientific inquiry skills and nature of science, they are still heavily loaded with scientific facts and concepts, particularly in the Hong Kong Advanced Level Examination (HKALE). This overly examination-oriented culture, along with other factors, has become the major constraint for science instruction moving towards greater emphasis on scientific inquiry and nature of science in Hong Kong.

Since 2009, a new senior secondary school curriculum has been implemented in Hong Kong, in which the original 2-year study for the Certificate of Education Examination (HKCEE) plus subsequent 2-year study for the Advanced Level Examination (HKALE) were replaced by a 3-year study leading to the Diploma of Secondary Education (HKDSE). The subject curricula at senior secondary also get major revisions. The new science curricula have put much more emphases on scientific inquiry, science-technology-society-environment (STSE) and nature of science (Curriculum Development Council and Hong Kong Examination Authority 2005). These changes in science curricula and public assessments give hope for a substantive transformation of science instruction in Hong Kong.

This study seeks to explore if a STSE approach to science instruction is feasible in Hong Kong schools. That means, the STSE course can, on the one hand, effectively address many important goals of science learning, namely scientific inquiry skills, NOS understandings and STSE awareness, while, on the other hand, meet the heavy demand of scientific knowledge in coping with the Hong Kong public exams.

The research questions of this study are:

1. How should a STSE biology course be developed so that it not only emphasizes scientific inquiry, nature of science and STSE relationships, but is also as effective as traditional class in the learning of scientific content knowledge?
2. What are the impacts of this STSE high school biology course, as compared to the traditional class, on the scientific literacy of Hong Kong students in terms of scientific content knowledge, scientific inquiry skills, understandings of nature of science, STSE awareness and attitudes towards science and science learning?

STSE education

STSE education has emerged as a major movement in science education since the 70s and remains one of the key emphases in the science education reforms worldwide nowadays (Pedretti & Nazir 2011). STSE generally refers to the curriculum and instruction that address the connections between science, technology, society and environment, and a comprehensive review of STS education has been made by Aikenhead (2002). Different from traditional curriculum that stresses the mastery of scientific content knowledge, STSE education has a major goal of developing social responsibility in collective decision making on social issues related to science and technology.

Aikenhead (1994) proposes a scheme of Categories of STS Science to classify the diverse STSE practices. Eight categories of STS science are ordered according to their priority given to STSE content: 1. Motivation by STS content, 2. Casual infusion of STS content, 3. purposeful infusion of STS content, 4. Singular discipline through STS content, 5. Science through STS content, 6. Science along with STS content, 7. Infusion of science into STS content, 8. STS content. The proportion of STSE content progressively increases from categories 1 to 8, along with decreasing emphasis of scientific content knowledge. Starting from category 4, the curriculum organization is determined by the STSE content rather than the internal structure of the discipline used by traditional science curriculum. Though it is hard to say which category represents ‘true’ STSE, research shows that students get additional benefits from STSE course in category 3 or above (Aikenhead 1994).

Pedretti and Nazir (2011) reviews 40 years of STSE education and identify six currents of STSE education: application/design, historical, logical reasoning, value-centered, sociocultural, and socio-ecojustice currents. This framework allows the classification of diverse STSE education by its different foci and aims. The

Application/design current centers on technology and practical problem solving. The historical current emphasizes understanding science from a historical perspective. The logical reasoning current is mainly about rational decision making for socioscientifc issues (SSIs). The value-centered current, on the other hand, addresses mainly the values and morals when dealing with SSIs. The sociocultural current places great importance on understanding science within a sociocultural context. The last one, socio-ecojustice current, is concerned more with actions than simply understanding.

As for the instructional approach, while traditional science is characterized by direct teaching, demonstration and experiments, STSE instruction usually makes uses of a wide range of interactive learning activities like role-play, discussions, simulations, games, decision making, debates and problem solving. Aikenhead (1994) suggests a general approach to STSE instruction (see Figure 1), in which instruction begins with a social issue, and then related technological and science concepts are drawn in. With the knowledge acquired, the social issues are revisited. This approach can make learning happen in a meaningful context.

As for the learning outcomes of STSE education, Aikenhead (2003) concludes that students in STSE classes, as compared to traditional class, can learn science content equally well or even better, significantly improve their understanding of the interactions among science, technology and society, notably develop their attitudes toward science and science learning, and make modest but significant gains in thinking skills, such as creative thinking, decision making, and application of science content to everyday situations. Nonetheless, the learning outcomes depend largely on a purposeful integration of STSE contents into the curriculum and the use of sound instructional strategies.

Scientific literacy

Scientific literacy (SL) is a major goal of science education in many reform documents, such as Science for All Americans (American Association for the Advancement of Science [AAAS] 1989) and Benchmarks for Science Literacy (AAAS 1993). A detailed analysis and comprehensive review of scientific literacy was made by Roberts (2007), in which two Visions of SL are distinguished. Vision I centers on the perspectives of science and scientists and therefore stresses the learning of scientific knowledge and skills, whereas Vision II centers on the sociocultural perspectives and stresses an understanding of the roles of society, cultures and values. While Vision I is criticized to be narrow, Vision II could not adequately address scientific skills and knowledge. These two Visions of SL, however, can be integrated with Pedretti and Nazir 's (2011) currents of STSE education, with the first three currents belonging to Vision I, and the last three Vision II.

Despite that there is "no consensus about the meaning, or even the constituent parts of SL" (Roberts 2007, 735), PISA, in its attempt to make an international comparison of scientific literacy, has constructed an operational definition for scientific literacy (HKPISA 2008): For the purposes of PISA 2006, scientific literacy refers to an individual's:

1. Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues.
2. Understanding of the characteristic features of science as a form of human knowledge and enquiry
3. Awareness of how science and technology shape our material, intellectual, and cultural environments,
4. Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen.

The first point refers to the application of scientific knowledge and the process of scientific inquiry. The second point concerns with the nature of scientific knowledge, and the third point is close to STSE. The last point is about attitudes towards science and STSE awareness. Based on this definition, a framework for the assessment of scientific literacy has been worked out by PISA, in which students are assessed on three competencies: identifying scientific issues, explaining phenomena scientifically, and using scientific evidence.

Scientific literacy, as defined above, has many shared goals with STSE education, making STSE approach a potentially appropriate means for achieving the goal of scientific literacy. Indeed, STSE has been the slogan for achieving scientific literacy in some countries such as Canada in the past decades (Aikenhead 2000). As stated in the national framework of science curriculum in Canada, scientific skills, knowledge and attitudes are best acquired through "the study and analysis of the interrelationships among science, technology, society, and the environment".

Design and Methods

This study employs a quasi-experimental design, in which two secondary 4 (grade 10) classes of a Hong Kong secondary school were taught about the same topic, human reproduction, with one class employing the STSE approach and the other class taught traditionally. The scientific literacy of the students of the two classes were assessed and compared.

The school was a band one school (intake of top 30% of primary students) and used English as the medium of instruction. All the students were Chinese with ages ranging from 14 to 16. They were allocated evenly into the two S4 classes according to their overall academic results in S3, so the average academic abilities of the two classes were similar. Both classes were taught by one teacher in order to reduce the variability stemming from the basic qualities of the teacher, though the teacher variable is still a significant and unavoidable factor when he attempted to teach in two different approaches.

Assessment of scientific literacy

Based mainly on the framework of PISA, scientific literacy was assessed in this study on six domains: 1. Recall of concepts; 2. Application of concepts in unfamiliar situations; 3. Scientific inquiry skills; 4. STSE awareness; 5.Understanding of the nature of science; 6. Attitudes towards science learning. Tests were constructed for the assessment of these domains, which were first validated by two science educators and then trailed in a group of about 10 students to improve their clarity and validity.

A test consisting of short-answer questions was constructed to assess the recall, understanding and applications of the biological concepts. Similar to PISA, several items were clustered into one unit under the same STSE context, such as the cloning of sheep, amniocentesis and in-vitro fertilization. To make the assessment fair, only the concepts covered by both classes were assessed and the contexts used were novel to both classes. The breadth and depth of the test are set in line with the biology certificate examination of Hong Kong in order to investigate if the STSE approach can cope with the heavy demands of the public examinations. The content and construct validity of the test were judged by two experienced biology teachers. Students of both classes took the test shortly after the course and the performances of the two classes were compared after adjusting for their biology scores in the last year using analysis of covariance (ANCOVA). This can compensate partly for the lack of pretest in the study.

A test for the assessment of scientific inquiry skills was constructed (see Appendix 1.) based on several sources: PISA's assessment framework and items, Test of Integrated Process Skills (TIPS) (Dillashaw and Okey 1980) and Biological Investigations Test (Germann 1989). The test consists of 22 multiple-choice items, which was validated independently by two experienced biology teachers. The test was administered to the two classes as pretest-posttest and the scores of the two classes were compared using one way analysis of covariance (ANCOVA).

The students' attitudes toward science, STSE awareness and understanding of nature of science were assessed by a Likert-scale questionnaire in a pretest-posttest manner. The items were adapted from some existing instruments: the Views on Science-Technology-Society (VOSTS) (Aikenhead and Ryan 1989) for the assessment of STSE awareness, the Inventory of Scientific Attitudes (Moore and Sutman 1970) for the assessment of NOS understanding, and the revised Inventory of Scientific Attitudes (Moore and Hill 1997) for the assessment of attitudes toward science and science learning. For each assessed construct, there are both positive and negative statements (Table I) and the scores of the two classes were compared by ANCOVA, with the pretest scores as covariates.

Table I. A sample of the Likert–scale items for the assessment of STSE awareness, understanding of nature of science and attitudes toward science

STSE awareness
● Only doctors have the right to decide on what treatments to be made on the patients, as they have best medical knowledge. (+)
● The patients and their families, rather than the doctors, should have the right to decide what treatments to receive, as the decisions affect themselves. (–)
Understanding of nature of science
● Some questions cannot be answered by science. (+)
● Anything we need to know can be found out through science. (–)
● A useful scientific theory may not be entirely correct, but it is the best idea scientists have been able to think up. (+)
● Scientific laws have been proven correct without any possible doubt. (–)
Attitudes
● Biology class is interesting. (+)
● Biology is the subject I dislike most. (–)

Note: The (+)/(–) denotes the informed/naïve views, or positive/negative attitudes.

STSE course and traditional course

The STSE course was designed by the researcher of this study together with the teacher of the classes. It was trialed in another class and the students were interviewed to collect feedback for the improvement of the course. In the design of the course, the first principle is to take account of the learning of the biological knowledge as required by the exam syllabus, thus leaving only about 30% of the instruction time to the development of the scientific inquiry skills, decision making skills, and understandings of nature of science and STSE connections. This emphasis on content knowledge is thought vital for the STSE course to be accepted by teachers and schools in Hong Kong under intense exam pressure. Another challenge is to identify clearly and minimize the knowledge outside of exam syllabus since students in Hong Kong are very pragmatic and exam oriented. However, this poses difficulty in the design of the course since many STSE themes would require much knowledge outside the exam syllabus.

There are four STSE themes in the course: 1. Intersexuality; 2. Teen sex and pregnancy; 3. Infertility; 4. The journey to become a mother. (See Appendix 2). These themes were carefully chosen for their relevance to the biological knowledge required by the exam syllabus, and their potentials to develop the skills, understandings and values regarding STSE connections, scientific inquiry and nature of science. In addition, these themes were deemed interesting to the students and could enhance their attitudes towards science.

With an emphasis on learning the required disciplinary knowledge, the STSE course developed in such a way belongs to the category of singular discipline through STS content in Aikenhead's (1994) categories. As for the six currents of STSE education as proposed by Pedretti and Nazir (2011), this STSE course is closer to the current of logical reasoning since it stresses rational decision making for socioscientific issues based on scientific knowledge and skills. Also, it addresses more the Vision I of scientific literacy by Roberts (2007). Despite that, values and morals are also addressed throughout the course, for instance, patient rights, respects for the intersexuals, and values related to abortion and contraception.

The teaching lasted for about two weeks using nine 40 minute lessons. A wide variety of interactive learning strategies were used in the STSE course such as, brainstorming, structured group discussion, open class discussion, jigsaw learning, case studies, debates, role plays, simulation, decision making, problem solving (See

Appendix 3) since interactivity is at the core of STSE instruction (Byrne and Johnstone 1988). For the learning of scientific knowledge, however, direct teaching is still the principle method employed. This is to ensure that the efficiency of content learning in terms of instruction time would not be compromised in the STSE course. Nonetheless, the STSE course is estimated to require 50% more instruction time than the traditional course in covering the same amount of content.

The teaching basically follows the sequence shown by Figure 1. Teaching starts from the socioscientific issues, then moves through related technologies and scientific knowledge, and finally returns to the issues for their resolution. The issues are resolved, bit by bit, along with progressive acquisition of relevant knowledge. Teaching shifts regularly between issues resolution and content learning so that students can learn on a need-to-know basis and apply their learning within meaningful contexts. Take for example, in the unit of intersexuality, the students first read the stories of an intersexual, from which the chllenges of determining gender are raised. Then, the reproductive systems and secondary sexual characteristics of man and woman are taught. With the knowledge learned, students revisit the issues to discuss which gender the person in the story should be assigned. The discussions, though largely rational and science-based, also address the rights and feelings of the intersexual.

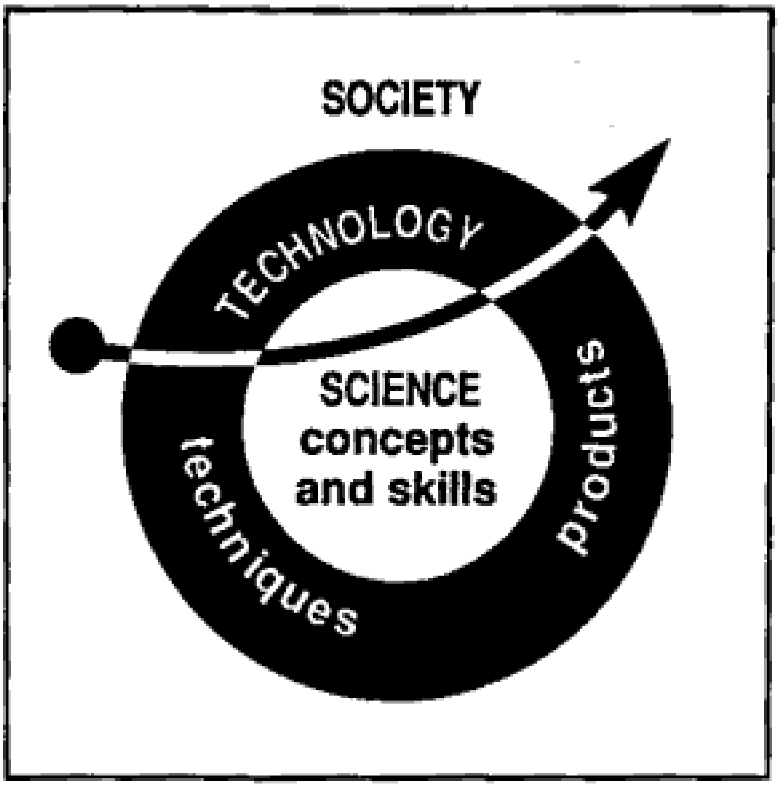

FIGURE 5.2 *A sequence for STS science teaching*

Figure 1. The instructional sequence of STSE (Aikenhead, 1994)

The traditional class was taught in a more "traditional" way: the biological concepts were presented first, followed by some of their applications in everyday life. It is closer to category 1 of Aikenhead's (1994) framework- motivation by STS content. The organization of the contents is mainly determined by the internal conceptual structure of the topic as in most traditional textbooks. For example, teaching started with the general anatomical structures of the male and female reproductive system, and then the detailed functions of each part are explained one after one. This organization makes the traditional course, as compared to STSE approach, more systematic in concept learning and students will be given the prerequisite knowledge before learning a new concept. However, the downside of this traditional approach is that the concepts are not learned on a need-to-know basis in meaningful contexts. Moreover, the traditional course does not play particular attention to scientific inquiry, nature of science, STSE interrelationships and sociocultural perspectives. Nonetheless, the instruction of the traditional class is not necessarily didactic. It was interactive using extensive class discussions and multimedia, but, as compared to the STSE course, it was more teacher-centered and did not have much student group discussions and independent work.

Results

Recall, understanding and application of biological concepts

A post-instructional test was administered to the both classes, assessing the recall, understanding and application of the biological concepts in the topic of human reproduction. The scores of the two classes were compared using ANCOVA, with the students' S3 yearly scores in biology as covariate. The results are shown in Table II. The STSE class not only performed as well as the traditional class in recall and understanding of concepts, but also outperformed the traditional class in application of concepts (p^2=0.06). The results are consistent with the literature that STSE approach is as good as or even better than traditional approach in content learning.

Table II. Assessment of the recall and understanding and application of biological concepts of the STSE and traditional classes

	Mean scores (adjusted for S3 biology scores)		Partial Eta squared
	STSE class	Traditional class	
Recall and understanding of concepts (18 marks)	14.55	13.75	0.02
Application of concepts (56 marks)	26.63*	22.88	0.06

*P<0.05

Scientific inquiry skills

The students' scientific inquiry skills were assessed by 22 multiple choice items in pretest–posttest format. The posttest scores of the two classes were compared using ANCOVA, with the pretest scores as covariates, and the results are shown in Table III. The overall posttest scores of the STSE class, after being adjusted for the pretest scores, are significantly higher than that of the traditional class, F(1,76)=15.46, p2= 0.11.

Table III. Scores of the scientific inquiry skills of the two classes, adjusting for the pretest scores.

Scientific inquiry skills	Posttest mean scores	Partial Eta squared

	(adjusted for pretest scores) STSE class	Traditional class	
a) Identify the questions that are scientifically investigable (21, 22)	**1.68	0.59	0.44
b) Identify the fair test for a research question/hypothesis (12, 13)	1.49	1.58	
c) Identify the dependent, independent, and control variables of a test (1,2, 3, 4,5,9)	4.72	4.96	
d) Define variables operationally (6,7,8)	2.05	1.75	
e) Identify the hypothesis for a research question/test design (10,11,18)	**1.49	0.58	0.31
f) Interpret graph correctly (14, 15)	0.85	1.03	
g) Draw valid conclusion from data/results (16, 17, 19, 20)	*3.08	2.67	0.05
Total	**15.46	13.07	0.11

*p <0.05, ** p<0.01 The numbers in the brackets show the item number.

Looking at the component scientific inquiry skills, the STSE class outperformed the traditional class in three skills, but other four displayed no significant differences. The two skills that the STSE class made positive outcomes, namely Identify the questions that are scientifically investigable and Identify the hypothesis for a research question/test design, are the inquiry skills that are seldom addressed in ordinary science classrooms of Hong Kong. But for other inquiry skills that are commonly touched upon in science teaching, such as the control of variables design, the outcomes of the STSE course were of no difference from the traditional course. The results thus demonstrate that the STSE course can address a wider scope of important scientific inquiry skills.

STSE awareness

The students' STSE awareness was assessed by a questionnaire consisting of 13 Likert–scale items in pretest–posttest. For the positive statements, the responses of Strongly agree, Agree, Disagree and Strongly disagree were given 4,3,2,1 points respectively, while the points given to the negative statements were reversed. A higher point thus represents views that are closer to the expert views. An ANCOVA was conducted to compare the posttest scores of the two classes, with the pretest scores as covariates. The adjusted mean posttest scores of the STSE and traditional classes are 3.03 and 2.92 respectively, with the STSE class scoring significantly higher than that of the traditional class, with a medium effect size ($\eta 2=0.06$) (see Table IV). The STSE course is particularly effective in promoting the awareness that science and technology play important roles in resolving social problems. That can be explained by the design of the STSE course in which the science and technologies are often given central role in dealing with the social issues.

Table IV. The STSE awareness of the STSE and traditional classes

STSE awareness	Posttest mean scores (adjusted for pretest scores)		Partial Eta squared
	STSE class	Traditional class	
a) The technocratic and democratic views on socio-scientific decision making	3.23	3.17	
b) The social responsibility of scientists	2.78	2.78	
c) The role of science and technology in resolving social problems	3.11*	2.88	0.07
d) Government/societal control of science	2.92*	2.73	0.05
e) The interdependence of science and technology	2.98	2.90	
f) The distinction between science and technology	3.21	3.18	
Total	3.03*	2.92	0.06

*P<0.05

Understanding of nature of science

Eleven Likert–scale items were administered to the students of the two classes in pretest–posttest. The statements were constructed in both positive and negative directions, representing the expert views and the naive views on the nature of science. For the positive statements, the responses of ‘strongly agree’, ‘agree’, ‘disagree’ and ‘strongly disagree’ are given 4,3,2,1 points respectively, while the points given to the negative statements are reversed. A higher point thus represents a better understanding of the nature of science. An ANCOVA was conducted to compare the posttest scores of the students of the two classes, adjusted for the pretest scores. The results are shown in Table V. Contrary to expectation, the adjusted posttest scores of the traditional class are significantly larger than that of the STSE class. This may be a result of the ceiling effects, inadequate duration of the treatment and the transfer problem from the contexts of the course to the general statements in the assessment instrument.

Table V. NOS understanding of the STSE and traditional class

Understanding of nature of science	Posttest mean scores (adjusted for pretest scores)		Partial Eta squared
	STSE class	Traditional class	
a) A scientist should be willing to alter his position on the basis of sufficient evidence.	2.94	3.38*	0.11
b) The laws and theories of science are approximations of truth and are subject to change.	3.07	3.16	
c) Science cannot provide correct answers to all questions	2.84	3.28*	0.27
Total	2.95	3.26*	0.16

* p<0.01

Attitudes

The attitudes of the students were assessed by a questionnaire administered as pretest and posttest. There are eighteen statements in the questionnaire that express both positive and negative attitudes toward biology learning, values of biology, self-concept in learning biology and attitudes toward science careers. For the positive statements, the responses of ‘strongly agree’, ‘agree’, ‘disagree’ and ‘strongly disagree’ were given 4,3,2,1 points respectively, while the points given to the negative statements were reversed. Therefore, the more points the students gain, the more positive attitudes they have. An ANCOVA was conducted to compare the attitude changes of the STSE and traditional classes (Table VI).

Table VI. The attitudes towards biology study and science of the STSE and traditional classes

	Posttest mean scores (adjusted for pretest scores)	
	STSE class	Traditional class
Attitude about biology study (6 items, total score =24)	19.29	18.78
Attitude about usefulness of biology (4 items, total score=16)	12.53	12.43
Self-concept in biology learning (4 items, total score=16)	10.16	10.03
Attitude about science careers (4 items, total score=16)	11.74	11.40
Total (scores=72)	53.71	52.63

*All attitude scores have no significant difference between the STSE and traditional classes

The overall attitudes and all the four component attitudes of the students after the instruction did not show significant differences in both the STSE and traditional classes. The short duration of STSE instruction may not be able to effect significant changes in attitudes.

Discussion and conclusions

Compared to the traditional course, the STSE course of this study produced better learning outcomes in application of scientific concepts, scientific inquiry skills and STSE awareness, but showed no significant differences in recall of scientific concepts and attitudes toward science learning. These findings are in general consistent with the STSE literature except for the lack of positive impacts on students' attitudes (Aikenhead 2003).

But the result that the traditional class outperformed the STSE class in NOS understanding is unexpected. The teaching about NOS has involved many difficulties and issues, which are reviewed by Lederman (2007). One of the issues is that NOS instruction has to be explicit and reflective, but the STSE course has to address a number of other objectives so that it may have not given adequately "explicit" attention to the NOS aspects. However, this still cannot explain why the traditional class showed even better performance than the treatment class.

The study has shed light on how to further improve the scientific literacy of Hong Kong students through reforming the traditional science curriculum and instruction. A STSE approach as designed in this study is deemed feasible in the exam-driven contexts of Hong Kong in view of its effectiveness and efficiency in learning scientific concepts. The key principles of designing this STSE course, though not all justified by the data, would provide reference for STSE curriculum development:

1. STSE themes are used for organizing knowledge of a science discipline - category 4 of Aikenhead' (1994) STS categories, which makes scientific concepts learned and applied in meaningful contexts.
2. A STSE course better puts more emphasis on the current of logical reasoning (Pedretti and Nazir 2010), which is more about rational decision making for socioscientific issues. As such, the STSE course can resonate with Liberal Study, a core subject newly introduced in Hong Kong in 2009. Too much emphasis on the moral, social and cultural aspects of SSIs may make the course resisted by science teachers and students under the highly exam oriented culture of Hong Kong.
3. STSE themes are carefully selected and constructed to ensure the coverage of curricular contents on the one hand, and minimize out-of-syllabus contents on the other hand. It is to make sure that the course is not regarded additional and irrelevant to examinations by teachers and students.
4. Scientific inquiry skills, STSE awareness and NOS understandings are extracted from the STSE contexts and explicitly targeted through a variety of learning activities. This makes the learning of these skills and understandings more holistic and contextual.
5. Instructional methods are principally direct teaching for scientific concepts so that the efficiency of content learning, in terms of instruction time, would not be severely compromised. The STSE approach had already used 50% more instruction time than the traditional class to give comparable learning outcomes on content learning. If a more student-centred approach is used, the STSE approach would take an even longer time to cover the same amount of content. But for other skills and values targeted by STSE education, more interactive, student-centered strategies are employed since didactic teaching is deemed not effective for these outcomes.

6. The instructional sequence is basically social issues-technology-science knowledge- technology-social issues so that the learning of science knowledge is contextualized on a need-to-know basis and elaborated through applications.

STSE approach, when following the above design principles, is even better than traditional teaching in the learning of scientific knowledge. The effectiveness of the STSE approach in concept learning hinges on the facts that science concepts are repeatedly learned and applied in varying contexts. This finding is important as it could alleviate to some extent the fears of teachers and parents that innovative teaching practices may compromise content learning and exam performances.

Some may argue that a STSE approach following the above design principles has given too much emphasis on scientific knowledge and skills, but not adequately addressed the values, cultures and morals inherent in the socioscientific issues. This is the tension between Vision I and II of scientific literacy (Roberts, 2007). The results of this study support that Visions I and II are not entirely incompatible: Students can learn scientific knowledge and skills in a robust manner (Vision I) even in the contexts of socioscientific issues where values, culture and personal opinions are addressed moderately (Vision II). These two aspects of scientific literacy are actually complementing to each other when students need to make informed decision in face of complex socioscientific issues.

In Hong Kong and other Asian countries, there are high expectations from students, parents and teachers for success in the highly competitive exams. Any curricular innovation has to meet these expectations in order to be well received. It is necessary for Hong Kong to develop an approach suited for its own context, because STSE education in different countries should give different priorities to different goals according to their own needs and circumstances (Aikenhead 2002). Besides, given the top science performance of Hong Kong students in PISA and TIMSS, it would be unwise to make drastic changes in the priorities of goals of existing science education. Rather, we should capitalize on our existing strengths to improve the quality of science education.

Nonetheless, the above conclusions are limited by the design and subjects of the study. The positive impact of the STSE course on concept learning may not happen on students of lower academic abilities since they tend to be more prone to the unsystematic content learning through STSE themes. On the contrary, these students may enjoy the class more due to its interactivity and real life contexts so that their attitudes towards science learning may get enhanced more appreciably.

The short duration of the course also limits the development of some skills and attitudes. At last, the teacher factor is also crucial, since STSE education would require a teacher to undergo "paradigmatic" changes in their educational beliefs (Aikenhead 2002). Teacher beliefs and capabilities are possibly the greatest barriers for extensive use of STSE approach for science instruction in Hong Kong.

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Appendix

1. A sample of assessment items for scientific inquiry skills

Chi Ming grew the mould in nine dishes containing the same amount and type of nutrients. Three dishes were kept at 0^oC, three were kept at 90^oC, and three were kept at room temperature (about 27^oC). The growth of the mould were observed and recorded after four days.

1. The purpose of this investigation is to find out how the independent variable affects dependent variable. What is the independent variable of this investigation ?
   a. Growth of bread mould
   b. Amount of nutrients in each dish
   c. Temperature of the dishes
   d. Number of dishes at each temperature

2. What is the dependent variable of this investigation ?
   a. Growth of bread mould
   b. Amount of nutrients in each dish
   c. Temperature of the dishes
   d. Number of dishes at each temperature

A study tests whether oil additive X will increase the efficiency of a car. Five identical cars each receive the same amount of oil but with different amounts of additive X. They are then tested on their efficiency.

7. How could the efficiency of a car be measured in this study ?
   a. Ask the passengers to evaluate how comfortable the car is when it is traveling.
   b. Ask the drivers to evaluate the efficiency of the cars during driving.
   c. Measure the distances each car travels on the same track until they run out of oil.
   d. Measure the noise produced by the car when climbing up a slope.

A farmer wants to speed up the production of tomato plants. His hypothesis is that the more water the seeds receive the faster they germinate.

13. How can he test this hypothesis ?
   a. Place seeds in different trays and give them different amount of water. Count the number of days the seeds take to germinate.
   b. Place seeds in different trays and give them different amount of water. Measure the height of the seedlings in different trays.
   c. Place seeds in different trays and give them different amount of water. Measure the amount of water used by the tomato seeds before they germinate.
   d. Place different numbers of seeds in different trays and give them the same amount of water. Count the numbers of days the seeds take to germinate.

2. The STSE themes and expected learning outcomes of the STSE course

STSE theme	Units	Scientific knowledge	STSE connections	Scientific inquiry skills and nature of science understandings
Intersexuality	1.1 Stories of intersexuals 1.2 How are man and woman different ? 1.3 How is sex determined? 1.4 Historical discoveries about sperm and eggs 1.5 Artificial selection of baby sex 1.6 Causes of intersexuality - Klinefelter syndrome and Androgen Insensitivity Syndrome 1.7 Social and	**Knowledge required by the syllabus** Structures and functions of male and female reproductive systems; Development of secondary sexual characteristics; Meiosis andm itosis; Chromosome, DNA and genes; Sex determination in humans **Knowledge outside the syllabus** Sexual differentiation in early embryo; Causes of intersexuality -Klinefelter Syndrome and Androgen Insensitivity Syndrome	1. The complex interactions between science and society in defining gender 2. Patient rights 3. Social responsibility of scientists and medical doctors 4. Technocratic and democratic views on socio-scientific decision making 5. Contributions and limitations of science and technology in	**Scientific inquiry skills** 1. Recognize scientifically investigable questions 2. Identify evidence needed for a scientific investigation 3. Propose alternative hypotheses 4. Identify dependent, independent and control variables in an investigation 5. Operationalize variables 6. Make predictions

	ethical issues associated with intersexuals		dealing with social problems 6. Relationship between science and technology 7. Government and social control on the development of science	based on hypotheses 7. Draw evidence-based conclusions 8. Evaluate conclusion critically 9. Reason quantitatively, e.g. how samples size and sampling method affect the interpretation of results, recognizing trends and patterns in graphs and data 10. Communicate science concepts and conclusion effectively to target audience **Nature of science understandings** 1. Science has its limitations, especially in dealing with social problems 2. The tentative and evolutionary nature of science 3. Science is not only done by experiments, but also by natural observations and
Teen sex and pregnancy	2.1 Survey on teens' attitudes toward sex			
	2.2 Contraception	**Knowledge required by the syllabus** Sperm and ovum; Menstrual cycle; Sexual intercourse and fertilization; Implantation;Contraceptive methods		
	2.3 Male contraceptive	**Knowledge outside the syllabus** Male contraceptives		
	2.4 Abortion	**Knowledge required by the syllabus** Embryonic development; Amniotic fluid;Placenta and umbilical cord		
	2.5 AIDS in Hong Kong			
Infertility	3.1 Causes and treatments of infertility			
The journey to become a mother	4.1 Prenatal examination and giving birth	**Knowledge required by the syllabus** Prenatal care; Breast-feeding;Vaccination;Birth process **Knowledge outside the syllabus** Signs of pregnancy; Pregnancy test;Calculation of date of		

		delivery; Mother's health and the foetus; Rhesus blood groups; Epidural anaesthesia; Signs of birth; Assisted birth and caesarian		theorizing.

3. Outline of Teaching

Each period lasts for 40 minutes

Period 1-2

- Motivation – show photos of intersexuals/transsexuals on internet
- Group readings on story 1 and story 2 (CL: each student in a group read out one paragraph in turn with Chinese)
- Class discussion to brainstorm questions about the stories (CL: round-table within group and then in the class)
- Class discussion on 'How males and females are different' (CL: pair share)- show transparency of boy and girl with and without clothes.
- Home assignment : 'How is sex determined : the role of genes'

Period 3-4

- Class discussion on 'How is sex determined : the role of genes'
- Group discussion to construct a set of best answers to be handed out (CL: pair share)
- Class discussion on the answers and lectures are given on some topics (video of Miracles of life, animations)
- Discuss historical ideas on reproduction
- Home assignment : 'Klinefelter syndrome'

Period 5-6

- Class discussion on 'Klinefelter syndrome'
- Group discussion to construct a set of best answers to be handed out (CL: pair share)
- Class discussion supplemented with lectures
- Home assignment : 'Androgen Insensitivity Syndrome'

Period 7-8

- Class discussion on 'Androgen Insensitivity Syndrome'
- Group discussion to construct a set of best answers to be handed out (CL: pair share)
- Class discussion supplemented with lectures

Period 9

- **Read news article - 'Sex reassignment' and discuss the legal restrictions on gender selection of HK**
- Test on the subject content, STS content and applications