Teaching creative thinking in regular science lessons: Potentials and obstacles of three different approaches in an Asian context

Vivian M. Y. CHENG

Department of Science and Environmental Studies
Hong Kong Institute of Education
HONG KONG, CHINA
E-mail: vcheng@ied.edu.hk

Received 30 Mar., 2010
Revised 29 Jun., 2010

Contents

Abstract

In response to the recent school creativity reforms in Asian places, this paper studied three different approaches of integrating creative thinking training into regular science lessons. They include developing creative thinking through science process, science content and science scenario. Three teacher case studies were conducted to examine the potentials and obstacles of implementing these approaches in classroom of Hong Kong. This study found that all the approaches were useful in developing student creative thinking, yet teachers experienced different tensions and dilemmas in different approaches. This paper suggests that the science content approach may be more readily accepted by teachers and students in an educational system which is dominated by knowledge content and examinations. However, with the limited skills and experience in creativity, teachers and students may feel that the science process and science scenario approach are easier to start with, as they are less constrained by the rigid content in the syllabus. Among various hindering factors, the most crucial one was found to be the original heavy knowledge-content, which in fact is a common characteristic of secondary science curriculum in many Asian places. In our future research and educational reforms, the dilemma between creative thinking and content learning needs to be seriously considered and solved at both individual and system levels.

Keywords: creativity education, science curriculum, Asian context

Introduction

Basic concepts of creativity

Creativity has growing significance in contemporary world, and received increased attention in recent educational reforms around the world. What is creativity? Sternberg and Lubart (1999) states, "creativity is the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (p. 3). In education field, creativity is believed to be a combination of abilities, skills, motivation, attitudes and other factors (Ripple, 1999). Among all these attributes, creative thinking is always considered as central to creativity development. From the cognitive approach, leading scholars of creativity consider divergent thinking as the essence of creative thinking (Guildford, 1950; Torrance, 1974). The most influential definition of divergent thinking includes the elements in Guilford's (1950) Structure of the Intellect (SOI) model: fluency, flexibility, originality and elaboration. In contrast, some scholars take an affective approach. For example, William's Taxonomy of Creative Thought (Williams, 1980) suggests that affective factors such as curiosity, imagination, challenge-taking and risk-taking attitudes are conducive to creativity development, and motivational factors like interest, value and confidence in creative thinking are also important determinants.

Creativity in Science Education

Creativity is an elusive concept and can be interpreted in a variety of different ways. So is creativity in science domain. Creativity in science education may aim at developing scientific creativity, as defined in Hu and Adey (2002) or some general creative thinking elements, as described in McCormack and Yager (1989). Creativity field is having an on-going debate on the domain-specificity and generality of creativity (Baer & Kaufman, 2005). This shed doubt on the transfer of creativity learning from science to other domains. On the other hand, the suitability of developing creativity of scientists in a "science for all" curriculum is controversial. There is still no conclusion to what should be the teaching objectives and instructional strategies of creativity education in science. For these reasons, a multi-faceted perspective for integrating creative learning into science education is easier to be accepted than a unidirectional one.

In a recent review of Kind and Kind (2007), they reported different perspectives in defining creativity in science education, and different approaches adopted by science educators, including poetry, inquiry-based science teaching, experimental methods, imagery and imagination. Cheng (2006) suggests multiple approaches to foster creativity in Physics education, including discovery, understanding, presentation, application, and integration of science knowledge. For infusing creativity into regular lessons, one may need to consider the approaches of existing science curriculum. For long, science content-based and science process-based are the two most common approaches in science curriculum (Swatton, 1990). Coming to recent decades, the science-technology-society (STS) approach grew in significance (Mansour, 2009). In parallel with these science curricula, this study suggests three approaches for integrating creativity into regular science lessons, i.e. developing creative thinking through science process, science content and science scenario.

Let's first discuss the science process approach. Open-inquiry is regarded as a most fundamental and widely used way to foster creativity in science education (Johnson, 2000; Kind & Kind, 2007; Meador, 2003). Craft (2000), Meador (2003) and Shahrin, Toh, Ho and Wong (2002) considered engaging students in the open-ended discovery and the scientific inquiry process could help to build new concepts, and develop creative thinking abilities and attitudes. Among all inquiry processes, hypothesis-making is considered as an essential one for creating connections between prior knowledge and new experiences, and also practices a critical element of scientific investigation and creativity enhancement (Starko, 2010, Watson & Konicek, 1990).

In the science content-based approach, creative writing, which involves the use of analogies, is another useful strategy in nurturing creativity in science education (Drenkow, 1992). Everyday analogies lead an individual to new ideas, and personal analogies (in which students are asked to be the thing) help to foster imagination (Girod, Rau & Schepige, 2003). Kind and Kind (2007) and Starko (2010) commented that such process of imagination in specific situations results in students' better understanding and new perspectives to science. In fact, the use of analogies has played a vital role in scientific discovery and invention (Gibbs, 1999). In light of this, creative writing is considered as an effective strategy for enhancing students' imagination, creative thinking and also understanding of science concepts.

In the science scenario approach, creative problem solving (CPS) is another common way to foster creativity in science education. It aims to offer students an opportunity to "work with open-ended problems or tasks that require creative solution" (Park & Seung, 2008, p.48). According to Isaksen, Dorval and Treffinger (2000), CPS model consists of six stages: mess-finding, data-finding, problem-finding, idea-finding, solution-finding and acceptance-finding. In each stage, divergent thinking (finding many ideas) is followed by convergent thinking (analyzing ideas and making choice). Several studies on science teaching (Gallagher, Sher, Stepien & Workman, 1995; Gallagher, Stepien, & Rosenthal, 1992) adopted CPS or other similar problem solving model, and demonstrated different degrees of success.

Context of the study

Hong Kong is a modernized Chinese city. Similar to Singapore, Taiwan, Korea, Japan and other Asian places, recently, Hong Kong is undergoing creativity-related educational reform. In Hong Kong, creativity has become one of the three most significant "generic skills" to be developed across all subject curricula (Curriculum Development Council, 2002a). The same as all other Asian places, creativity is suggested not to be taught as a separate subject, but to be infused into the regular curriculum. Sciences are subjects in which creativity elements should be integrated in all levels (Curriculum Development Council, 2002b). However, the creativity reforms of Hong Kong were confronted with many obstacles and dilemmas (Cheng, 2004; Craft, 2005; Hui & Lau, in press). It has a centralized examination-orientated educational system with heavy knowledge-dominated curriculum and Confucian-heritage classroom culture. Almost all Hong Kong teachers have little, if any, experience in teaching creativity. In fact, all these characteristics of teachers, curriculum and culture are quite common in educational systems of Asian places (Cheng, in press).

Research question

Based on the literature review, this study developed different approaches for integrating creative thinking training into regular science lessons. They included developing creative thinking through science process, science content and science scenario. In science process approach, teachers may infuse creative thinking training in the some open-inquiry processes. In science content approach, teachers may nurture creative thinking through application of science content in creative writing. In science scenario approach, teachers may engage students in CPS tasks which started with a science-related scenario. This study aimed at understanding the potentials and obstacles of these approaches to science classroom in Hong Kong. Through the case studies of three teachers, it examined the process and outcomes of teaching which adopted these approaches, and also revealed the tensions and dilemmas of teachers in their preliminary teaching of these approaches.

Method

A large-scale school-based creativity project was launched to introduce creativity elements into Physics, Chemistry, Biology and integrated science subjects of Form 1 to Form 6 in secondary schools of Hong Kong (corresponding to Years 7 – 13 in the UK). The project adopted an infusion approach, in which regular lessons were restructured for direct instruction in thinking skills and processes (Ong & Borich, 2006). The teachers of this project received about ten hours of creativity training and conducted some simple try-outs of creative teaching. Afterwards, the teachers were free to choose one of the three creative science teaching approaches, according to their own backgrounds and preferences. They then designed their own creative science activities based on their students' needs and school syllabus.

Three teachers of similar backgrounds, each adopting a different approach, were chosen to the samples of case studies. Teacher A adopted science process approach, asking students to generate new hypotheses. Teacher B adopted science content approach, inducing creative writing tasks on the science concept taught. Whereas Teacher C adopted science scenario approach and conducted a creative problem solving (CPS) activity which started with a science-related problem situation. The three teachers came from different secondary schools, all of which are of average academic standard in Hong Kong, and use their mother-tongue, Cantonese, as the medium of instruction. The three teachers had 5 to 14 years of teaching experience, and all were novices at creativity teaching. One important point is that these teachers were free to choose the creativity approach which most suited their own teaching styles, student abilities and school curriculum. For this reason, this study assumed that each creativity approach under examination was implemented by a suitable teacher in a suitable classroom context, in the school-based creativity project described.

This study examined the process, outcomes, tensions and dilemmas in the teachers' initial attempts of implementing the creative activities in their regular science lessons. Data were collected from teacher and student interviews, analyses of students' work and in-depth lesson analyses of a few selected lessons. Each case study reported in the following session includes the background of the teaching, the teaching and learning process and their evaluations.

Results of teacher case studies

Case 1: Making hypotheses

Teacher A was an experienced teacher who had been teaching biology for more than ten years. Before joining this creativity project, he was already keen in engaging students in scientific inquiries, but he only emphasized logical thinking side. In this study, Teacher A deliberately induced two short hypothesis-making exercises into a biology lesson on the unit "The Digestive System", in a Form 4 class of 47 students of age 15 to 16. Through these exercises, he wished to develop students' divergent thinking abilities and strengthen their hypothesis-making skill.

In the first exercise, Teacher A raised a question, *"Why are some people more resistant to tooth decay?"* Students were asked to write down as many as ten possible answers (i.e. hypotheses) in about five to ten minutes. Although most students could provide some reasonable answers (e.g. do not eat any sweets), they failed to provide as many as ten answers. Moreover, most of their answers were similar. For example, a student gave answers like: "do not eat sweets", "do not eat marshmallows", "do not eat chocolate", "do not eat chewing gum", and so forth. Their answers showed low flexibility in generating ideas from various perspectives. On the whole, Teacher A was not satisifed with the quantity and quality of answers given by his students.

On the next day, Teacher A deliberately used a similar question to assess students' progress, *"How can the rate of tooth decay be increased?"* Again, students were required to propose as many as ten possible hypotheses in about five to ten minutes. This time they were able to suggest more answers than before. Many of them could write down ten answers. Their answers demonstrated higher diversity, ranging from unbrushing teeth to having more snacks. Teacher A reported that there was an improvement in student flexibility in generating ideas. He attributed such encouraging progress to the debriefing of the objectives of the activities after the first try-out. Teacher A explained the assessment criteria to the students that one mark would be given for each reasonable hypothesis, and bonus marks would be awarded to novel answers and answers from different perspectives. No similar information was given to students before students' first hypothesis making exercise.

Apart from these problems, Teacher A reported a number of tensions and dilemmas. First, some students felt confused of the purpose of this activity. A student raised his hand and questioned, "Why are we doing such an exercise? It seems out of the syllabus." The student made such a comment probably because he knew such kind of tasks would not appear in tests or examinations.

Second, some students did not have enough confidence or they did not understand what teacher requested, especially in the first try-out. They often asked the teacher questions such as "Can I write this?", or "Is this answer correct?" It appeared that they were not comfortable with open-ended questions. Probably, they assumed there were model answers to the questions, as that in their usual learning.

Third, students' attitudes towards the creative activities tended to go to two extremes. Five students were interviewed. Two of them said that they liked it very much and wanted to do more of this kind of exercise. They felt that they had progression in suggesting more answers, especially more innovative ones than before. Nonetheless, the other two said that such exercises were a waste of time, as they seemed irrelevant to the syllabus. Their performance was poorer than other classmates, and their improvement between the two exercises was not so obvious. Apparently, the two try-out teachings were not effective to all the students.

Fourth, some of their answers revealed their misconceptions in the topic. For example, a student suggested that drinking pure water could prevent tooth decay. Teacher A criticized that it was not precisely accurate, as water cannot prevent tooth decay unless fluoride is added. He did not accept answers which deviated from scientific facts taught in the science class, even though it was a creative learning activity.

Fifth, there were discrepancies between the behavior of the students and the expectations of the teacher. Teacher A expected his students to propose hypotheses that were meaningful to science investigations and daily-life application. Teacher A complained that some students gave non-serious answers for the first question, e.g. “no teeth”, “artificial teeth”, “eat nothing”, and “too much saliva” (in Cantonese it means talking too much). Similarly, in the second try-out, students gave responses like “eating lemon” (which implies “being rejected by your loved one” in Cantonese). It seemed that some of the students preferred humorous, joke-making answers, whereas Teacher preferred science-related serious answers. However, as the teacher had not fully explained his expectations, obviously there were some communication problems between Teacher A and his students. In reflective discussion, Teacher A reported that he was in a great struggle on whether he should keep an open mind, or to stop students from giving irrelevant or inappropriate answers. In this try-out process, Teacher A did reflect on some questions which he had never thought of before, and demonstrated in-depth reflection through this new attempt.

Case 2: Creative Writing

Having been teaching physics for six years, Teacher B was already a very skilful Physics teacher with high confidence in his teaching. Teacher B had taught the unit "Properties of Light" in Form 3 Physics for several years. He complained that students just tried to memorize some main points and examples in it, instead of really understanding the concepts. Teacher B tried to infuse creative writing activities in this unit in order to enhance more in-depth study of this topic, and, at the same time, fostering student creative thinking.

In one Form 3 Physics lesson, Teacher B asked 30 of his students aged 14 to 15, and of average academic standard, to spend about ten minutes writing a short story starting with "I am a light beam emitted from the sun." He asked his students to introduce scientific facts into the passage, and to express their imagination in writing. He also informed students that their writings would be assessed, using two criteria. First, marks were given to all correct scientific concepts or knowledge, no matter whether they were related to optics or not. Second, writing with personal analogies would be given additional marks.

In the creative writing, a few students demonstrated higher abilities in both creative thinking and application of science concepts. Table 1 shows one of the best writings collected from the class. It mentioned concepts of optics such as light being able to pass through a vacuum, reflection, refraction, ultraviolet rays, and the green house effect. The writing was dramatic, with application of metaphors and personification. For example, carbon dioxide was described as a security guard, and the light beam entering the Earth was described as someone crossing the border. This student was able to make empathetic connection with non-living things, which was a high level of personal analogy (Joyce, Weil & Showers, 1992). Both the applications of light concepts and the innovative portraits of the scientific phenomena of these outstanding students have impressed Teacher B. He believed that this creative writing exercise could reinforce the student's science content learning and train their creativity.

I am a light beam emitted from the sun. I went to a planet called Earth. On the way, I could not talk with my companions. I could not even see them. However, when I saw some light spots, I knew they had collided with something. I prayed that I would not follow them. I hoped I could arrive on Earth. After a journey of thousands of years, I eventually reached the ozone layer of Earth. Alas! My body became lighter, because the ultraviolet rays and some other energy could not cross the border. Oh! My friends were greeting me. I could see them and talk with them now. I asked them why and they said we were reflected by air particles. I was impressed by the beautiful city in front of me. I collided with the ground powerfully and rebounded into the sky. However, carbon dioxide, the security guard at the border, did not allow me to leave and sent me back to the ground. I lost my balance and fell into the sea. I felt my body was splitting, and different parts of my body diverged in different directions. I did not expect that my first journey to Earth would also be my last…

***Table 1**: Sample creative writing rated as excellent (translated from Chinese)*

However, not all students had this level of performance. Average students were able to mention three to four properties of light or phenomena of light waves in the writing, demonstrating their understanding of the science contents. Table 2 shows a sample of writing ranked as average by the teacher. The passage mentioned science concepts, such as melting, photosynthesis and evaporation. However, most descriptions were just about some daily-life phenomena without dramatization or innovation. In fact, merely replacing "the light ray" with "I" was the lowest level of personal analogy (Joyce, Weil & Showers, 1992). In Teacher B's class, most students were at this level, with limited imaginative thinking in their creative writing work.

I am a light beam emitted from the sun. I have traveled through space. After a hard journey, I eventually arrived on Earth and shone on the ground. I melted the ice at the South Pole and the North Pole. I provided energy to plants for photosynthesis so that they could grow healthy. I dried the clothes for the housewives by evaporating the water inside. I shone on children's face, energized them and brightened their future. Although I am just a light beam emitted from the sun, I possess a lot of power.

***Table 2**: Sample creative writing rated as average (translated from Chinese)*

Teacher B faced some difficulties in the teaching. Students' performance varied. About ten students worked slowly and cheerlessly, and could only write about two to three sentences. Teacher B asked them why, and they said that they could not think of any more points. It seemed that some students lacked of the creative writing skills, and also the motivation to complete this difficult exercise. In reflective discussion, Teacher B reported that it was important to encourage those students to drop down as many points or sentences as they could, no matter they were good or not. Some of them could write more with this kind of encouragement.

Another dilemma faced by Teacher B was the lack of lesson time. As restricted by the heavy curriculum, Teacher B reported that he could only spend little time on the creative writing exercises. Like Teacher A, Teacher B only assigned ten minutes in class to the creative tasks. He solved the problem by asking students to complete the writing at home. Teacher B believed that students could do better if they were given more time for discussion in class.

Case 3: Creative problem solving (CPS)

Teacher C was a young teacher who had several years' junior Science teaching experience. She wished to enhance students' interest in science through creating a playful and happy atmosphere in creative activities. After some preliminary try-outs, Teacher C induced a partial CPS model into a Form 2 lesson on the science unit "photosynthesis". The class had 42 students, aged 13 to 14, and of average academic ability. Teacher C asked students to imagine "what would happen if all plants were to disappear from the earth". The teacher guided the students through two CPS steps: problem-finding and idea-finding.

In the problem-finding step, students were active to suggest their answers aloud. Some answers were scientific (e.g. unbalanced proportion of oxygen and carbon dioxide, landslides, broken food chain, and etc.), while some were related to daily life (e.g. no paper to use, birds cannot live on trees, gardeners would lose their jobs, and etc.). After brainstorming 12 problems, Teacher C asked the students to vote for one single problem for further discussion. Eventually, the majority of the class chose the problem of "constipation" caused by the lack of fruit and vegetables.

The class moved on to the idea-finding step in which they suggested multiple solutions to solve the problem of constipation. Some students suggested reasonable solutions (e.g. using laxatives, intestinal lavage, etc.). However, many other students gave irrelevant answers or those with misconceptions (e.g. vomiting, washing the anus, etc.) Obviously, some students deliberately made jokes for fun, and enjoyed other classmates clap hands or laugh at their answers. At the end, the whole class came up with 10 solutions to the constipation problem collectively.

Teacher C was happy to see that students were excited and responsive in the lessons. Although the activity lasted for only about 20 minutes, the class generated quite a number of ideas. Many students raised their hands and provided their answers voluntarily. Some shouted out their answers directly. Her classroom was full of laughter. She enjoyed the pleasurable and exciting atmosphere of her class. Moreover, she believed students' interest in creative thinking and the topic of "photosynthesis" was enhanced through this kind of activities.

In spite of this enjoyable classroom time, Teacher C was facing some challenges. As a young and playful teacher, Teacher C had an open mind to accept students' crazy and wild ideas, however, her students might think differently. Five students were interviewed after the lesson. All of them reported that their dominant feeling in the class was happy and "high". And yet, most of them criticized that "the lesson like playing more than learning" and "Why should we do this activity? It is not useful to examination."

After discussing with her mentor, Teacher C admitted that her CPS teaching had room for improvement. In the lessons that followed, Teacher C conducted several more CPS exercises with debriefing, metacognitive discussion and transfer of learning. She asked her students to find out the characteristics of this problem solving strategy, its strengths and weaknesses, and when and how to apply it in daily-life. Her student performance in CPS tasks became more satisfactory. In follow-up interviews, some students reported that this CPS strategy stimulated their thinking, and was useful to their daily-life.

Though Teacher C started her CPS task with a topic-related scenario (i.e. around plant), the discussion on constipation was obviously deviated from the photosynthesis content in the original syllabus. As Teacher C had spent considerable teaching time on CPS activities, with some of them quite unrelated to the content, she later found that she needed to arrange extra lessons to complete the original science syllabus before the mid-term examination of her school. In final reflective discussion, Teacher C commented that infusing CPS activities into the science curriculum was much more difficult than she originally assumed.

Findings and discussion

Potentials

The above case studies illustrated some initial attempts to infuse creative elements into science teaching by three secondary teachers, who were novices at creativity teaching. They varied in their creative science teaching approach. Teacher A aimed at nurturing student *creativity through science process*. He expected that engaging students in making multiple new hypotheses could enhance their divergent thinking abilities in scientific inquiry. Teacher B aimed at nurturing *creativity through applying science content*. He expected that creative writing activities could train students' imagination and flexibility in presenting science knowledge. Teacher C aimed at nurturing *creativity through exploration started from a science-related scenario*. She expected CPS activities could help students to develop divergent thinking and problem solving skills.

In results of this study, all three teachings were successful to some extent. Teacher A found that his students became capable of generating new hypothesis, and the quality and quantity of them increased in his second teaching. He considered this an improvement of creative thinking in science process. Teacher B found some students produced high-quality creative writings with both good application of scientific concepts and innovative metaphors, whereas, average students also managed to produce acceptable writings with some simple science concepts and personal analogy. In both level of performance, some degree of imagination and understanding of science concepts were demonstrated. For Teacher C, her interesting open-ended PS task readily stimulated students' divergent thinking, and her improved CPS teachings further strengthened students' problem solving skills. In sum, positive learning outcomes of students were obviously found in all three cases. In fact, student gains went beyond their creative thinking. In all three cases, some students reported that their interests in the science topic (i.e. light ray, tooth decay or plant) were much increased after the creative thinking activity. Especially in the case of Teacher B, both the teacher and the students believed that the creative writing activity strengthened student conceptions of light ray and consolidated what had been learnt in lesson.

On the other hand, the interviews with the three teachers revealed that, despite the difficulties in the teaching process, all of them believed that the activities were worth trying. Why so? They used to say "the activities are good for students". From the activity design and pedagogical practices they developed, the three teachers had learnt how to make use of open-ended tasks (in science content, process or scenario) to stimulate divergent thinking, imagination and other creative attributes. Furthermore, all the three teachers demonstrated deeper level of professional reflection, in face of the tensions and dilemmas in their new teaching approach.

In short, in all the three cases, the creative teaching and learning exerted some positive impacts on both teachers and students. This study revealed that even teachers novice at creativity education, with minimal training, were capable of designing activities of these three approaches and implementing them in regular science classroom, with certain degree of success. Though with obstacles, it was worthwhile to explore these three kinds of creative science teaching approach in Hong Kong context.

Obstacles

The three teachers experienced a number of tensions and dilemmas in the try-out process. It was found that there were similarities and differences in their problems and their coping strategies. Let's elaborate them in details here.

Content-domination

In education system of Hong Kong, secondary school science curriculum and examinations were still dominated by content knowledge. For Teacher A, though he aimed at creativity in science process, he could not always "put down" his concern about science content. He was dissatisfied with students' inaccurate science concepts and science irrelevance. Comparatively, Teacher B showed less dilemma of this kind, as he aimed at fostering creative thinking through applying science content. In assessment, he allocated equal marks to both correct use of science content and imaginative thinking. However, his dual requirements made the task difficult, especially to some low-ability students. For Teacher C, she started with a science-related scenario in her CPS activity. She allowed her students to make free choice in the problem-solving process. Ultimately, her class discussion deviated from subject content and even science domain. Though Teacher C was rather open-minded in accepting non-science-related discussion in her science lessons, however, her students felt confused and not satisfied. Her students were under the tensions of the examinations and their established learning habit.

These three case studies showed that teachers were in the dilemma of content and creativity teaching, though this dilemma was demonstrated in different ways in different cases. Teaching creative thinking through science scenario (but not directly related to the subject content) may be complained by students that it is not useful, teaching creative thinking through science process may fail to cope with science content learning in parallel, whereas, teaching creativity in applying science content may be too difficult to students, who had limited science concepts and creative thinking abilities. Creative thinking is divergent and open-ended in nature. Therefore, in the development of creative thinking, it is very difficult to restrain student thoughts to some fixed-ended science contents, and, on the other hand, the exploration around a convergent content provides limited room for creative thinking. The dilemma between content teaching and creative thinking is basically a struggle between divergent and convergent style of teaching. And, the root of this dilemma is the heavy knowledge-content of science curriculum in Hong Kong.

Time constraints

Time constraints were found to be common to all the three teachers. The activities of the first two cases were deliberately designed to be simple and short, and teachers gave the students less time than needed. And, all the three teachers reported that their creative teaching used more time than expected. It is a great challenge for teachers to cope with the constraints of the curriculum and fulfill the requirements of creative teaching at the same time. The three teachers taking different teaching approaches were found to adopt different methods to cope with this time constraint. In interview, Teacher A reported that he asked his students to do self-learning in the school web for some less core knowledge contents, in order to spare time for the creative activities. Teacher B gave less than enough time for students to complete the creative writing, and asked his students to complete them at home. Teacher C reported that she arranged extra after-school lessons to complete the syllabus after doing this project. In terms of time management, Teacher C was in the worst situation. She needed to teach back all the science content in a separate period of time, whereas, Teacher A covered, at least, some ideas in the content (i.e. tooth decay) together with the creative activities. Of course, the time pressure to Teacher B was the least, because the creative activity was simply an extension of his normal content teaching, which could be easily accepted by his students as a take-home exercise.

Discrepancy in expectations

The discrepancy of expectations between teachers and students is also a problem in all the three cases. Teacher A, as an experienced science teacher, always insisted that imaginative and creative elements should not override science knowledge, accuracy or relevancy. He were expecting some scientifically correct and yet creative or novel ideas from his students. However, his students were more inclined to the playful and humorous aspects of creative thinking. Teacher A puzzled on how to respond to joking answers in the hypothesis-generating exercises, and struggled whether he should keep an open mind. In fact, Teacher B's view on creative science teaching was very similar to that of Teacher A. The major difference is that Teacher B explicitly instructed students to produce writings with both creative thinking ideas and correct science concepts. Teacher B and his students could very quickly compromise in the assessment criteria which emphasized both aspects. It seemed that both Teacher B and his students did not have too much puzzle on why doing this creative writing exercise, as it could consolidate both the content knowledge and elicited imaginative thinking. In contrast, some students of Teacher C were very serious with their learning and did not accept this kind of playfulness in science class. These students' conceptions of science learning were obviously restricted to learning of science content which would be tested in examinations. In fact, all the three teachers found unexpected discrepancies between teacher and students, and their student performances were below their expectations at the beginning of their try-outs. As being inexperienced in creativity teaching, the three teachers tended to oversimplify the integration of creative thinking training into a knowledge-dominated science curriculum.

Student abilities and interest

As classrooms of Hong Kong have a Confucius-heritage Culture, and most students have so limited experience in creative thinking learning. Their difficulties in completing teachers' creative tasks could be easily understood. Even if students could come up with some ideas, they hesitate to respond and they worry whether their answers are appropriate. At the beginning, both Teacher A and C did not explain the learning objectives and the rationales of the creative activities. As a result, students did not understand the teachers' expectations or the purposes of the activities. This increased their puzzles and confusion. Teacher B directly informed the assessment criteria to his students, who therefore became aware of the requirements and purposes of the creative writing exercises. However, his students still felt the exercise demanding. The creative writing exercise required students to grasp hold of a number of related science concepts accurately, some basic personal-analogy writing skills and also the ability to integrate the two. With the limited science knowledge, writing skills and imagination, students found it difficult to create good writings on that specific topic. Moreover, the subject content in science syllabus of Hong Kong usually belongs to "hard science" and not so daily-life. Students may find the creative tasks built around these topics remote and uninteresting. Like in the case of Teacher B, students might have low interest in writing a passage on "If I am a light beam….". Comparatively, taking the other two approaches, teachers might be less restricted by the subject content at hand and found themselves more room to develop interesting creative tasks to suit their students (like the case of Teacher A and C).

Furthermore, obvious student differences in motivation and ability were found in all the three cases. Although some students enjoyed the activities and performed well, there were also other students who disliked them and performed poorly. This is a big challenge to teachers' professional competence in taking care of these individual differences in a classroom of more than forty students in Hong Kong. The causes of these individual differences and their coping methods are worthy of further investigation.

In sum, this study found that all the three approaches had their strengths and limitations. Students had different gains in the three activities, including both creative thinking and content learning. In the creative science teaching, all the three teachers were experiencing tensions from content-teaching, time constraints, student abilities and interests, and discrepancies between teacher and student expectations. Adopting science content approach, students found it difficult to integrate the content and the creative thinking, whereas, teacher might find it hard to design easy and interesting creative activity around the content at hand. Adopting the science process approach, teacher worried that the discussion was irrelevant to the subject content in the syllabus. Adopting the science-related scenario approach, teacher lacked of time to cover the original science syllabus and students complained the learning was not useful to their examinations. All these teaching dilemmas in fact were rooted in the content-dominated curriculum in Hong Kong.

Conclusive Remarks

The paper reflects that there are at least three approaches for infusing creative thinking elements into normal science lessons, i.e. through science process, science content and science scenario. In fact, this study made no final conclusion as to which approach is better. It seems that the science content approach would be easier to gain recognition in an educational system which is dominated by knowledge content and examinations. However, with the limited skills and experience in creativity, teachers and students might feel that the science process and science scenario approach easier to start with, as they are less constrained by the rigid content in the syllabus. All three approaches have their potentials and problems. Curriculum reform is such a complicated process, which has no simple direct path. Studies on multiple approaches of creative teaching are likely to be more beneficial to science education field than a unidirectional one. In future, science educators should try to develop more useful teaching strategies and learning activities for each approach, and further examine their strengths in various teaching contexts.

Educators should also be aware that all the three approaches have their limitations and constraints. They need to address several problems, including the original content-curriculum, time constraints, student interests and abilities, and the discrepancies between student and teacher expectations. These problems were originated from discrepancies in the divergent nature of creative thinking and the convergent nature of content-teaching, and that inside the local educational system (such as public examinations, rigid core curriculum, overloaded time-table, big class size and etc). Among all these sources of problem, the heavy knowledge-content of existing curriculum is considered as most crucial in creating teacher tensions and dilemmas in creative teaching. Educational policy-makers should seriously attend to the dilemma between this heavy content and creativity development in future reforms. Inevitably, creativity reforms would bring adaptation problems to both teachers and students who are unfamiliar with this new way of learning and teaching. Teachers and students need to readjust and reconstruct their teaching and learning methods, classroom expectations, communication methods and conceptions of science teaching and learning.

In fact, heavy knowledge-content and examination-oriented curriculum, CHC classroom culture and teachers and students being novice at creativity are all common characteristics in educational systems of many Asian places. Therefore, the result of this study somehow can reflect, or at least partially reflect, the situation of creativity education reform in many Asian places. It sheds light on the potentials and obstacles of the three creative science teaching approaches in other places which are undergoing similar educational reforms.

In future, to better understand the potentials and obstacles of the three approaches, further studies of the three creativity approaches in different educational contexts, including both Eastern and Western ones, are necessary. Another suggested area of future study is the interaction of teachers and approaches. For instance, teachers of different teaching styles and skills may perform quite differently in different creativity approaches. In future, researchers may further explore these complicated interacting relationships.

Acknowledgement

Sincerely thanks to Mr. Ken Ng, Mr. Sit Kwok Wing, Mr. Ho Chun Yan and Miss Angel Wong and Miss Xia Beibei for their kind support and assistance in the publication of this article.

References

Abell, S. K. (1990). The problem-solving muse. *Science and children, 28*(2), 27-29.

Baer, J., & Kaufman, J. C. (2005). *Creativity across domains: Faces of the muse*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Cheng, V. M. Y. (2004). Progress from traditional to creativity education in Chinese societies. In S. Lau, A. N. N. Hui & G. Y. C. Ng (Eds.), *Creativity: When East meets West* (pp. 137-167). Singapore: World Scientific Publishing.

Cheng, V. M. Y. (2006). A comprehensive curriculum framework for infusing creativity learning into physics knowledge learning. *College Physics, 18*(3), 15-19.

Cheng, V. M. Y. (In press). Infusing creativity into classroom of Eastern context: Evaluations from student perspectives. *Thinking Skills and Creativity* (2010), doi: 10.1016/j.tsc.2010.05.001

Craft, A. (2000). *Creativity across the primary curriculum:Framing and developing practice*. London; New York: Routledge.

Craft, A. (2005). *Creativity in schools: Tensions and dilemmas*. London: Routledge.

Curriculum Development Council. (2002a). *Basic education curriculum guide: Building on strengths (primary 1 - secondary 3).* Hong Kong: The Education Department, HKSAR Government.

Curriculum Development Council. (2002b). *Science education: Key learning area curriculum guide (primary 1 – secondary 3)*. Hong Kong: Curriculum Development Council.

Drenkow, J. (1992). Creative writing in a life science classroom. *Science Scope. 15*(4), 18-20.

Gallagher, S. A., Sher, B. T., Stepien, W. J., & Workman D. (1995). Implementing problem-based learning in science classrooms. *School Science and mathematics*. *95*(3). 136-146.

Gallagher, S. A., Stepien, W. J., & Rosenthal, H. (1992). The effects of problem-based learning on problem solving. *Gifted Child Quarterly, 36*(4), 195-200.

Gibbs, R. W. (1999). Metaphors. In M. A. Runco & S. R. Prirzer (Eds.), *Encyclopedia of creativity* (pp.209-219). San Diego, CA: Academic Press.

Girod, M., Rau, C., & Schepige, A. (2003). Appreciating the beauty of science ideas: Teaching for aesthetic understanding. *Science Education, 87*(4), 574-87.

Guildford, J. P. (1950). Creativity. *American Psychologist, 5*, 444-454.

Hu, W., & Adey P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education, 24*(4), 389-404.

Hui, A. N. N., & Lau, S. (In press). Formulation of policy and strategy in developing creativity education in Hong Kong: A practitioner's perspective. *Journal of Creative Behavior.*

Isaksen, S. G., Dorval, K. B., & Treffinger, D. J. (2000). *Creative approaches to problem solving: A framework for change* (2nd ed.). Williamsville, N.Y.: Creative Problem Solving Group-- Buffalo.

Johnson, A. P. (2000). *Up and out: Using creative and critical thinking skills to enhance learning*. Boston, Mass.: Allyn and Bacon.

Joyce, B., Weil, M. & Showers, B. (1992). *Models of teaching.* Boston: Allyn & Bacon.

Kind, P. M., & Kind, V. (2007). Creativity in science education: Perspectives and challenges for developing school science. *Studies in Science Education, 43*(1), 1-37.

Mansour, N. (2009). Science-technology-society (STS): A new paradigm in science education. *Bulletin of Science, Technology & Society, 29*(4), 287-297.

McCormack, A. J., & Yager, R. E. (1989). A new taxonomy of science education. *Science Teacher, 56*(2), 47-48.

Meador, K. S. (2003). Thinking creatively about science: Suggestions for primary teachers. *Gifted Child Today, 26*(1), 25-29.

Ong, A. C., & Borich, G. D. (2006). *Teaching strategies that promote thinking : Models and curriculum approaches*. Singapore: McGraw-Hill.

Park, S., & Seung, E. (2008). Creativity in the science classroom. *The Science Teacher, 75*(6), 45-48.

Ripple, R. E. (1999). Teaching creativity. In M. A. Runco & S. R. Prirzer (Eds.), *Encyclopedia of creativity* (pp.629-638). San Diego, CA: Academic Press.

Shahrin, M., Toh, K., Ho, B., & Wong, J. (2002). Performance assessment: Is creative thinking necessary? *Journal of Creative Behavior, 36*(2), 77-87.

Starko, A. J. (2010). *Creativity in the classroom: Schools of curious delight* (4th ed.). New York: Routledge.

Sternberg, R. J. & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In Sternberg, R. J. (Ed.), *Handbook of creativity*. Cambridge: University Press.

Swatton, P. (1990). Process and content in the national science curriculum. *School Science Review, 72*(259), 19-28.

Torrance, E. P. (1974). *Torrance tests of creative thinking*. Lexington, MA: Personnel Press.

Watson, B., & Konicek, R. (1990). Teaching for conceptual change: Confronting children's experience. *Phi Delta Kappan, 71*, 680-685.

Williams, F. E. (1980). Creativity assessment packet. East Aurora, N.Y.: DOK.