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Infusing creativity into Eastern classrooms: Evaluations from student perspectives

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ABSTRACT

Infusing creativity elements into regular classroom was an important movement in recent Asian educational reforms. A large-scale research study was conducted in Hong Kong to explore the possibilities, outcomes and difficulties of this kind of curriculum change from students' perspectives. Based mainly on Western creativity literature, this study developed a set of methods for infusing creativity learning elements into regular science lessons. After its implementation, students perceived improvements in their attitudes, conceptions, abilities and behaviors in creative science development. Students characterized this creative learning as a kind of active and playful learning which encouraged them to think boarder and wider, to appreciate creative ideas, and to develop their curiosity, confidence and initiation in learning. Though this classroom reform originally aimed at creativity development, students considered better understanding of science knowledge and positive attitudes towards science learning as their major gains. Students' high-order creative developments, such as novel and innovative thinking, challenging authority and risk-taking attitudes, metacognitive development and transfer of learning, were found to be weak. In further analysis, these outcomes were found to be related to some typical characteristics of Eastern culture and educational system. This study argued that creativity education, which adopted this kind of infusion approach, was likely to be restrained by the subject curriculum, local educational systems and social cultures. It provided additional support to the domain-specific, contextual-based and cultural-embedded characteristic of creative learning. Some suggestions were made for creativity reforms in Asian societies.

1. Introduction

1.1. Creativity education reform in the East

Nowadays, it is an international trend to integrate creativity in curriculum frameworks (Le Metais, 2003). Recently, governments of Hong Kong, Mainland China, Taiwan, Singapore, South Korea, Israel and other Asian countries have imposed curriculum reforms, which emphasized creativity development in their primary and secondary schools. One common feature of these countries is that they all recognize the importance of creativity across the curriculum, such as science, language, arts and so on. To cultivate creative citizens, Asian countries are undergoing vigorous education reform in a top-down process, in the strong support of their governments.

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In Hong Kong, creativity is now one of the three most significant "generic skills" to be developed across all subject curricula (Curriculum Development Council, 2002a). Like the situation of other Asian areas, the curriculum structures and the subject contents of the new curricula of Hong Kong did not have fundamental changes. In its suggestion, creativity is not taught as a separate subject, but to be infused into the regular curriculum, which is still highly conventional and knowledge-centered. Asian places are now in need of effective methods to infuse creativity elements into their regular classrooms (Cheng, 2004a).

1.2. Creativity development

In cognitive approach, divergent thinking first considered as the essence of creativity (Guilford, 1950). Cropley (2001) and Plucker and Runco (1999) recognized that the most popular method to enhance creativity in the past half a century has been the teaching of divergent thinking and the idea-generation strategies. Towards recent years, multiple and diverse perspectives were taken in creativity development (Fisher, 2004; Nickerson, 1999; Starko, 2010). In Vygotsky' theory, imagination, both a cognitive and affective attribute, is considered to be crucial in enhancing creative thinking (Eckhoff & Urbach, 2008; Lindqvist, 2003). Runco (1991, 1994, 2003) highlights the ability in problem-finding and evaluative thinking, whereas Mumford (2001) and Davis (2004a) draw attention to problem sensitivity in creative process. Teachers should encourage self-expression, individual construction of meaning, and personal creativity instead of consensual creativity (Runco, 2003, 2004, 2007). Student ideas are considered as creative if they are novel to students themselves, rather than breakthroughs to the field (Kaufman, Plucker, & Baer, 2008). Metacognition development, abilities in transfer and self-regulation of creativity are also highlighted in many recent studies (Davis, 2004a, 2004b; Fautley & Savage, 2007). In social psychology approach, Amabile (1996) and Hennessey (2000) suggest that creativity development is energized by intrinsic motivation rather than extrinsic motivation. Sternberg (2000) recommends that "a decision to be creative" is ultimately most crucial to the creativity development of a person. Combining the views of all these profound Western scholars, a full model of creativity education should include various cognitive and skill-based trainings, as well as the development of student interest, value and confidence in creativity pursuits.

1.3. Creativity in school curriculum

Governments of different places are developing curriculum models for integrating creativity into various subject contents. In *Eastern* places, Hong Kong government curriculum documents have suggested some general principles for developing students' creativity. It is stated that teachers should ask students to go beyond the given information, allow them time to think, strengthen their creative abilities, reward their creative efforts, value their creative attributes, teach them creative thinking techniques and the creative problem solving model, and create a climate conducive to creativity (Curriculum Development Council, 2002b). In Middle East, Israel initiated a new national educational policy called "pedagogical horizons for learning", which aimed at shifting education towards a focus on higher order thinking and deep understanding (Zohar, 2008). Similarly, governments of Singapore, Taiwan, Korea and Japan are also offering guidelines for teachers to foster creativity of students in various school subjects. In *Western* countries, England government proposed 5 kinds of student activities for creative learning, including questioning and challenging, making connections and seeing relationships, envisaging what might be, exploring ideas and keeping options open, and reflecting critically on ideas, actions and outcomes (QCA, 2005, p. 2).

Apart from government efforts, a number of researchers and scholars have studied how to integrate creativity into school curriculum. In USA, "Project Zero" study suggested learning experiences in multiple intelligences, arts, portfolio assessment, and creating a culture of thinking would foster creativity and understanding across school subjects (Veenema, Hetland, & Chalfen, 1997). Costa (2008) and Costa and Kallick (2000, 2009) suggested that school education should aim at developing 16 habits of mind, many of which are related to creativity development, including creating, imagining, innovating, thinking flexibly, questioning, posing problems, use of all senses, responding with wonderment and awe, taking responsible risks, thinking interdependently, thinking about thinking, and remaining open to continuous learning.

Williams (1969, 1986) has proposed a comprehensive creativity curriculum model. It consists of the interactions of three dimensions—subject matter content, classroom teaching strategies and student behaviors (i.e. learning outcomes). He suggested 18 teaching strategies for creativity development, for example, use of analogies, discrepancies, provocative questions, examples of change, creative writing, visualization skills and etc. The student behaviors in Williams' model included the cognitive ones (fluent thinking, flexible thinking, original thinking and elaborative thinking), and the affective ones (favor of risk-taking, complexity or challenges, curiosity and imagination). While many other literatures only suggested pedagogical methods, Williams offered a structural three-dimension model for creativity education across school subjects. Together with its empirical supports, Williams' model was still a useful reference for constructing creativity curriculum (Chan, 2005; Chen, 1995; Cheng, 2002; Maker & Schiever, 2005).

1.4. Creativity-related studies in science education

Science is recognized as one of the important subjects for developing creativity (Curriculum Development Council, 2002b). As early as in the 1980s, McCormack and Yager (1989) proposed a taxonomy of science education which included an "imagining and creating" domain. Adopting their taxonomy, Gilbert (1992) suggested six kinds of questioning for teaching creativity – association, imagination, brainstorming, organization, analogy and metaphor and reconceptualization. More creativity-focused studies emerged in science education field in recent years. Cheng (2004b) presented a comprehensive set of strategies for developing physics learning activities to foster student creativity. Hu and Adey (2002) suggested a scientific creativity model, which included questioning, problem solving, divergent thinking and other thinking elements in scientific imagination, investigations and inventions. Cheng (2006) also proposed a comprehensive model for infusing creativity elements into school Physics curriculum. In a recent review, Kind and Kind (2007) found that there were different approaches of fostering creativity in science education, including open-inquiry, creative problems solving, creative writing, metaphors and analogies, and etc. On the whole, empirical study on how to infuse creativity elements into regular school science lessons, especially in Asian context, was still lacking.

1.5. Approaches in creativity education research

With government's emphasis on school reform of creativity education, various training programs have been provided for the development of students' creativity. In literature review of creativity training programs (Fishkin, Cramond, & Olszewski-Kubilius, 1999; Hunsaker, 2005), what had been well-documented were mostly creativity training of stand-alone approach, i.e. some programs outside the school curriculum. Recently, there were more discussions on teaching for creativity across school curriculum (Craft, 2000; Fautley & Savage, 2007; Fisher & Williams, 2004; Wilson, 2005). However, empirical research studying the infusion of creativity teaching into regular school curriculum was still in need. Vong's research (2008), which studied teacher perspectives in fostering children creativity in kindergartens, was one of the significant ones in *Chinese* places.

Another recent trend in *Western* studies of creativity education is the emphasis on students' perspectives. Instead of focusing on practitioners' perspectives on curriculum design and instructional methods, researchers concerned more on the students' learning in classroom discourse (Jeffrey & Craft, 2004). Creativity educators and researchers recognized the importance of characterizing creative learning process from student perspectives (Craft, 2005; Craft, Cremin, & Burnard, 2008), and the inclusion of student voices in creativity education reform (Craft, 2005). However, creativity studies focused on students' perspectives were still lacking in *Asian* places.

1.6. Tensions in creativity school reforms in Eastern culture

In the famous cross-cultural comparison study of Hofstede's (2001), most Asian and Chinese societies were found to have high ranking in power-distance and long-term orientation, but low in individualism dimension. Though, in the past, Hong Kong had a long-term British rule, Hofestede's study revealed that Hong Kong's culture, in nearly all dimensions, still highly resembled the characteristics of Asian societies. It has a high level of emphasis on collectivism, as compared to individualism. Collective societies give priority to a group interests over individual interests. Influenced by this collectivist culture, classrooms in Asia tend to have discipline and conformity than that in the West. Chinese people are also comparatively more careful in observing strong hierarchies in relationships and do not tend to challenge the superior. Reflected in classrooms, teacher domination and authority are distinctive features. Students are used to following teachers' instructions without questioning. Chances are students usually keep silent and sit still in class. The "long-term orientation" dimension is considered as a major virtue taught in Confucian. In long-term oriented societies, people tend to value actions and attitudes that affect their future, instead of immediate happiness and enjoyments. This cultural orientation may be related to the hard-working and persistence of Asian students (Bond, 1996; Hofstede, 2001; Hofstede & Bond, 1988; Hofstede & Hofstede, 2005; Ng & Smith, 2004a, 2004b).

The discrepancies among the intended, the implemented and the assessed curriculum were well-recognized in educational studies over the world (Gvirtz & Beech, 2004; Keys, 2005; Kwon, 2004; Menis, 1994), Asia countries are of no exception. Much effort has been put in promoting creativity in Asian classroom, however, its outcomes might have been influenced by the collectivistic and Confucian culture (Cheng, 2004b; Craft, 2005; Ng & Smith, 2004a). Ng and Smith (2004b) found that teachers in Singapore viewed creative students as more disruptive than other students. Whereas Jang's study (2009) revealed that, though the implementation of innovative curriculum in Taiwan schools led to the enhancement of students' creativity, yet only few students liked such curricular innovations due to the influence of examinations. For many years, Hong Kong's creativity education was also criticized to be hindered by its rigorous academic approach for meeting the requirements of exam-driven system (Yojana, 1996).

1.7. Research questions of this study

Asian places were in need of researches which studied the infusion of creativity learning elements into regular school curriculum, addressing the existing constraints of local contexts, and evaluating it from student perspectives. This study had chosen Hong Kong, a modernized Chinese city, and science subject learning as its contexts. It aimed at understanding what kind of creative learning could be most readily induced into Hong Kong classroom, how students of Hong Kong characterized this kind of creative learning, what students' perceived learning outcomes were, and what they valued and preferred in this creative learning process.

Let us clarify two frequently used terms in this paper. In general documents, creative learning refers to any learning that stimulates learner creativity (QCA, 2005). Similarly, "creative learning" in this paper implied learning, through which student creativity could be developed, or was intended to be developed. Whereas, "creative teaching" in this paper referred to the teaching that fostered, or intended to foster, creativity of students.

2. Curriculum design proposed by this study

This study had adopted the embedded or infusion approach, in which creative thinking was taught within a subject context (Johnson, 2001; Ong, 2006; Swartz, Fischer, & Parks, 1998). Based on the Western literature, this study had attempted to develop a comprehensive method for infusing a wide range of creativity-learning elements into science subject content. The new curriculum model included creativity-based learning objectives, teaching strategies for achieving each objective, and various types of science learning activities, in which these creativity-learning elements were embedded.

2.1. Creative science learning activities

Concept and knowledge learning is always the core element of conventional science curriculum in Hong Kong and many other Asian areas. If creativity learning elements are infused into the current curriculum, it may be essential to start off the curriculum redesign process from subject knowledge content, and to explore all possible types of creative learning activities in relation to science content knowledge. Sternberg (2003) suggests "in teaching students to process information creatively, we encourage them to create, invent, discover, explore, imagine and suppose" (p. 333). With reference to science education literature reviewed in Section 1.4, this study has developed five different kinds of creative science learning activities, namely, discovery, understanding, presentation, application and transformation of science knowledge.

To elicit creativity through discovery activities, teachers may ask students to conduct independent open inquiry project, or simply engage students in divergent thinking exercises on science process skills. Students are encouraged to generate multiple and novel ideas in making scientific observations, doing classifications, asking scientific research questions, forming hypotheses, designing experiments and measurement methods, using equipments or tools, and making inferences from empirical data. Piaget (1976) suggested that "to understand is to invent". To understand science knowledge in an inventive way, teachers may encourage students to seek new alternative examples, analogies, descriptions, elaborations and explanations of the scientific theories or concepts in the lesson content. Furthermore, teachers may encourage students to reconstruct their previous science conceptions through exposing students to conflicting ideas, engaging them in the debate, confronting their beliefs with opposing evidence (Driver, 1994, 1996). Creativity may also be elicited through presenting science knowledge in various forms of expression. For instances, science concepts and principles can be presented in the forms of role-play, drama, song, drawing, poem and story. To apply science knowledge creatively, students are given unfamiliar or novel situations, in which they try to seek new or personal ways to explain scientific phenomena, to make predictions, to solve problems, to suggest inventions or to imagine the unknown. For transformation of science knowledge, students try to suggest changes to existing formal science knowledge. Students are encouraged to question and criticize the science knowledge in the textbooks, to find alternatives to them or to develop new ways to integrate them. (Examples of these creative science learning activities can be found in Appendix A.)

In fact, these five kinds of creative science learning activities resembled that suggested by QCA (2005) of England. For example, the scientific discovery involves questioning and challenging, the understanding of science knowledge involve making connections and seeing relationships. Furthermore, these five kinds of instructional designs also include some of the teaching strategies suggested in Williams' model and Project Zero. For example, presentation of science of science knowledge involves the use of analogies, creative writing and visualization skills. On the whole, the above-mentioned five types of pedagogical suggestions can be considered as methods to infuse creativity learning into science subject content.

2.2. Creativity-based learning objectives

The next concern is what are the basic learning objectives of the above five types of creative science learning activities. Based on literature discussed in Sections 1.2 and 1.3, a comprehensive set of learning objectives and pedagogical methods are proposed for creativity education. For objectives, it involves both cognitive and affective learning objectives. First of all, cognitive objectives are designed to include divergent thinking abilities of students. They include fluency (ability to generate many ideas), flexibility (ability to generate many different types of ideas, or ideas from many different perspectives), novelty (ability to generate unusual and original ideas), and elaboration (ability to add details to improve ideas). Besides divergent thinking abilities, the instructional designs in this curriculum model also aim at fostering students' sensitivity (being observant, intuitive, quick and capable in discovering changes, differences and problems), imagination (ability to think into the future, the impossible and the unknown), evaluative thinking (ability to make accurate judgments or decisions on the quality of ideas generated) and synthesis (ability to integrate divergent and convergent thinking, basic knowledge and skills to produce new and useful products).

For affective aspects, this model proposes that schools should promote students' appreciation of creativity, and their motives in creative thinking, including their interest, confidence and values in creative thinking. It is also important to cultivate students' curiosity, imaginative mind, favor of complexity and challenges, and willingness to take sensible risks.

Besides these cognitive and affective attributes, the proposed curriculum model also aims at equipping students with some useful creative thinking strategies, including brainstorming, mind-mapping, forced association, synetics, attribute listing, checklisting, visualization and creative problem-solving. Aligned with many Western creativity educators, this study considers the student development in metacognition of creativity, personal creative thinking techniques and creative thinking strategies as important learning objectives.

For teachers' reference, this study had further developed some instructional strategies for each of the above learning objectives, with examples of learning activities in Physics, Chemistry, Biology and general science. In addition, strategies for cultivating creativity-conducive learning environment, and subject-based creativity assessment were also proposed in this curriculum model.

3. Methods

3.1. School implementation

In order to try-out the curriculum model in Section 2, a large-scale, school-based creativity project, funded by Hong Kong government (Quality Education Fund), was launched in Hong Kong. This project lasted for more than 3 years and involved more than 30 local secondary schools. It had adopted the infusion approach, in which creativity learning elements were infused into regular science lessons. A group of more than 30 secondary science teachers were recruited on a voluntary basis. In 2 years' time, these teachers participated in a series of workshop of about 20 h. Experiential learning method and lesson redesign method, similar to that of Paul (1991), were adopted in the teacher training. Meanwhile, teachers conducted small-scale try-outs and had constant sharing of their experience in the workshops. Afterwards, the teachers implemented the creativity learning elements into their daily science lessons in full-scale for about 4–6 months. Teachers were encouraged to design their own activities and assessments to suit the specific needs of their students and their school teaching schedules. In this project, though the trainings were compulsory, teachers were given complete freedom to choose learning objectives, teaching strategies, science topics, pace and frequency of implementation.

This study was an evaluation of the school-based creativity project, from student perspectives. A group of interested teachers infused their self-designed creativity learning elements into regular classroom in normal school contexts. The instructional methods described in Section 2 were only used as a reference for teacher training (and also as a comparison in the final discussion of this paper). Teachers were not forced to implement the whole curriculum model. This study employed a mixed methods approach which involved the use of quantitative self-evaluation questionnaire instruments and semi-structured focus group interviews simultaneously. The use of separate quantitative and qualitative method is to offset the weakness inherent within one method with the strengths of the other method (Creswell & Plano-Clark, 2007). Findings in this study were validated by triangulation of these two methods.

3.2. Evaluation by student questionnaires

To evaluate the creativity reforms in classroom teaching of those teachers, both qualitative and quantitative studies were conducted on their students. Teachers in the project volunteered themselves in joining this quantitative study. Schools of different academic levels were involved. Each class had about 40 students. All subjects were Chinese, mainly aged 13–15. They were students of Form 2, 3, and 4 (equivalent to grade 9, 10 and 11 in England). All students and teachers in this sample had not got any special creative learning or teaching experiences before joining this project.

For the quantitative study, two student self-evaluation questionnaires were developed. First one is a "Creative learning characteristics" questionnaire which was developed based on the curriculum design proposed by this study in Section 2. It consisted of 70 items, covering perceptions on creativity-related science learning activities, classroom environment, thinking styles, and assessment. It asked students in what ways they found their science learning in the implementation period was different from their previous one. This questionnaire was administered to about 400 students of 10 classes in 7 different secondary schools. In analyzing data collected by this questionnaire, simple descriptive statistics were computed to understand the creative learning experience of the students.

The second one is "Creative learning outcomes" questionnaire, which was developed, with reference to Basadur and Hausdorf (1996), Hu and Adey (2002). It consisted of about a hundred items, widely covering students' perceptions on their conceptions, attitudes, thinking abilities and daily-behaviors which were related to creativity development and science learning. A five-point Likert scale was adopted for most of the items. This questionnaire was administered to about 280 students of 7 classes in 5 different Hong Kong secondary schools, before and after the creative teaching. In analyzing data collected by this questionnaire, compared means analyses (t-tests) were conducted on the scores of each of the items in pre- and post-questionnaires.

3.3. Evaluation by student interviews

In parallel with the quantitative study, semi-structured, focus group student interviews were conducted. About 30 students from 7 different schools were chosen from the whole project group, with a balance of high and low academic achievers. They were interviewed at the end of the implementation period, so as to understand student perceptions on their creative learning experiences and learning outcomes. In the interviews, students were asked (1) what were the major differences between this learning experience and that in their usual science lessons; what were the major characteristics of this kind of learning; (2) what they thought they had learnt, gained or inspired in these learning experiences; any changes to their feelings, abilities, thinking, beliefs, attitudes or knowledge; how they learnt these elements; (3) what problems they have encountered in this learning process; any suggestions for improvements. In data analysis, the student feedbacks collected were categorized into three groups – the student-perceived characteristics of the creative learning, the learning outcomes perceived by the students, and the problems they perceived and suggestions for improvements, if any.

4. Results

In school-implementation, about 30 teachers from different schools reported substantial creative teaching in their science lessons. About half of them claimed that they had infused creativity elements into their science classes at full scale (that meant, in maximum intensity which teacher felt suitable) for 4 or more months. Altogether more than a hundred teaching reports were collected (please refer to Appendix A for a summary of creative science learning activities reported by the teachers). Details of these teaching reports can be found in Cheng (2008), together with a full review of this project. In the record of this study, the creative science learning activities, which students had engaged in before joining the interviews, included open inquiry, problem-solving, creative writing, making metaphors and analogies, creating drama, rewriting songs, inventing new products and etc.

4.1. Characteristics of the science lessons – from student interviews

A total of more than a hundred student feedbacks were collected through interviews. In analysis, these feedbacks informed us several important student views on creative learning.

4.1.1. More active learning style

Nearly all students feedback that this learning experience was quite different from their regular ones. None of them said no differences. Some of them even had surprise and novel feeling in the process. When asked what the differences were, many of them reported a more *active learning style*. They perceived the lessons to have less rote learning, reciting, teacher lecturing, but more activities, more practices, more student participation, more chances to interact with classmates and more self-initiated.

> "In other lessons, we are required to *recite and learn a lot of things by memory. No need to do so in this lesson*."
>
> "There were *more activities than usual*. Usually, not that many. . ."
>
> "Very *novel* indeed! In the past, it was the teacher who gave instructions. This time, it was up to us to choose."
>
> "I felt *surprised*, as in physics classes, we usually do calculations and experiments only."
>
> ". . .I *took more initiative* to *discuss with my classmates* and ask questions. I used my brain to think more. . .."

4.1.2. Playfulness

The second most dominating feedback was the *playful feeling*. More than half of the students expressed that the learning experience was interesting, playful, happy, and gave them a lot of fun and satisfaction. Some had this feeling simply because they liked the activities, including making rocket-shoot, doing home experiments, creating songs, singing in class, watching and explaining magic show, and etc. Some others indicated that they especially enjoyed the relaxed and warm atmosphere which gave them less pressure but more freedom.

> "Compared with others, this class was much *more attractive and interesting*. . ..You would not feel bored."
>
> "Very *entertaining*! *Free to express*. Not by rote learning. Meanwhile, I could also learn from the classmates."
>
> "Really amazing, usually, no such chance to *play* like that. . .we pretend to be an electron!"
>
> "What makes us happy is that we could watch the (magic) show and do the activities. No need to sit still, listening to the teacher only. It was *nice to have activities, have something to watch and something to laugh at*."
>
> ". . .the lesson was *very relaxing, not under great pressure as usual*. . .."

4.1.3. Self-actualization

Among these students, some further emphasized that they got intrinsic fulfillments as they were given chances to express themselves, to solve problems on their own, and in fact to *actualize themselves*.

> "There were many opportunities for us to imagine in this class. Great fun! The class was very interesting, as it allowed us to *actualize* ourselves."

"I felt strange and happy, as we were asked to sing songs unexpectedly (in a Physics lesson)! I was happy that I could *create (it) by myself*, and *try my own ideas*. . ."

"There was *a huge sense of satisfaction*. Because I made it myself! I felt *a sense of achievement*."

"(In normal time,) we also have some group discussions in regular classes, but. . .. this time, 'playing' this kind of activities made me feel interested to think. Actually, there are few opportunities of this kind. I really had *a sense of achievement* this time and felt eager to think."

4.1.4. Creative thinking elements rarely mentioned

Compared with the responses on the playful, self-actualizing and active learning style, this study found that much less number of students mentioned creative thinking elements as major characteristics of their creative learning experience. Out of all 30 students, only two described explicitly some creative teaching arrangements done by their teachers. And, only a few students managed to describe some characteristics of creative thinking in their learning experience, for example, teachers purposely asked them to seek alternatives or to generate many possibilities.

"In fact, teachers seldom teach the word 'creativity'. Creativity was *infused in the lesson*, rather than having a lesson which deliberately teaches creativity. We rely on ourselves and try on our own. There were always debriefings after teaching."

"It was not long after the beginning of the semester that we started to have such kind of activities. We have (them) about once a month."

"In this class, I could think of what I have never thought of before. Whatever wild ideas!"

"Compared with other classes, there were *more interactions and exchanges* in this class. It *freed my imagination*."

"Past lessons seldom had this kind of activity. . ..there were *activities that asked us to seek many answers and think about many possibilities*. We eliminated some of them based on our prior knowledge and then tried out those remaining ones."

4.1.5. Sophisticated creativity-related learning characteristics not mentioned

Students did feedback creativity element in science learning, yet quite rare. Also, the more sophisticated creativity-related learning characteristics were nearly absent. No students reported that, in these lessons, they were encouraged to think or solve problems in novel or original ways, to make mistakes or to take risks in class, to imagine the impossible or to explain the unknown, to self-monitor or self-assess their own thinking, or to decide what to learn and how to learn. Furthermore, none of the students mentioned directly terms like "brainstorming", "divergent thinking", or that of other specific creative thinking abilities and strategies. The absence of these expected results may imply that either students were not so much impressed by the creative thinking part of the learning experience, or teachers had not implemented this part of the creativity curriculum effectively, or both.

4.2. Characteristics of the science lessons – from student questionnaire

The student response rates of all 70 items in the "Creative learning characteristics" questionnaire were analyzed. The items with most and least positive response rate were listed in Table 1. Among them, most students feedback that they had more opportunities to appreciate creative ideas, especially that of their classmates (71%), and to think broader from different perspectives (66%), both of which were rather basic level elements in creativity learning. The "playful and active learning style" reported in the interviews could also be identified in the questionnaire results. About 60–65% of students confirmed that this science learning gave them more opportunities to learn in relax and playful atmosphere, participate in novel and diversified learning activities, exchange with classmates, and explore things which they were interested in.

Items with lowest student response rate were also reported in Table 1. Less than half of the students reported that they agreed with these items. Among all 70 items, doing high-risk tasks and challenging the authorities ranked the bottom two. Least number of students feedback that their lessons had more opportunities to take risks (39%), to challenge the textbooks or teachers (39%), and criticize scientific theories (44%). From many students' perspective, as before, their mistakes, uncertainties and ambiguities were not generally accepted by teachers (42%), and their creative ideas received no special support or praise, but criticism (40–46%). On the whole, the findings in the questionnaire aligned with that in the student interviews.

In sum, students did perceive significant changes in their learning experience, and these changes involved some positive characteristics. However, the qualitative and qualitative studies quite unexpectedly found that, creative thinking elements were either not commonly reported by students or only the "lower-order" ones were mentioned, for example, the appreciation of creative ideas and thinking in more perspectives. In contrast, "high-order" elements like risk-taking, challenging authority, acceptance of ambiguities were least mentioned. And yet, most students characterized the creative science learning as a playful and active learning experience.

Table 1
Student response rate of individual items in "Creative Learning Characteristics" questionnaire ($n = 400$).

Compared with previous sciences lesson, in recent ones, I have more opportunities to	Percentage of students (%)		
	Strongly agreed or agreed	Neutral	Strongly disagreed or disagreed
Most positive response			
Appreciate creative ideas of classmates.	70.9	24.1	5.0
Appreciate creative items.	70.4	24.6	5.0
Think broader and more from multiple perspectives.	66.0	27.6	6.3
Learn in a relaxed and playful atmosphere.	64.8	27.6	7.5
Experience creativity in science.	64.0	29.4	6.5
Participate in diversified classroom learning activities.	63.3	30.2	6.5
Participate in novel learning activities.	63.2	30.0	6.8
Exchange ideas with my classmates, stimulating each other's thinking.	62.3	32.2	5.5
Freely explore things I am interested in.	60.3	29.4	10.3
Least positive response			
Challenge difficult and abstruse questions.	47.4	39.3	13.4
Tolerate day-dreaming and wild thinking occasionally.	46.3	37.3	16.4
Express my ideas without being criticized.	46.1	43.8	10.1
Obtain support and encouragement, rebuild confidence in difficulties.	44.7	41.2	14.1
Criticize some science theories so as to find out its weakness.	44.2	44.0	11.7
Tolerate making mistakes, uncertain answers or ambiguities.	41.7	39.1	19.2
Gain others' praise for my creativity.	40.0	44.5	15.6
Question the viewpoints in the textbooks and those of teachers.	38.9	43.7	17.3
Risk doing some tasks which have higher possibility of failure.	38.5	41.0	20.6

4.3. Learning outcomes perceived by students – interview results

4.3.1. Science-focused learning outcomes

4.3.1.1. Gains in science knowledge. Rather unexpectedly, among the hundred feedbacks in student interviews, learning outcomes related with science knowledge were most frequently mentioned, many more than that directly related with creativity or creative thinking. Many students (more than 70%) commented that the learning experience helped them to gain deeper understanding, better memory of the science subject content, and/or also to obtain extra science knowledge. There was evidence that these positive knowledge outcomes were related to the active and playful learning style perceived by student. In their reports, students related their gain in science content with their chances to think over the science content, to ask questions on it, to do activities and experiments on it, to apply it to daily life, to develop the solutions themselves, to discuss with classmates, and etc.

> "This class was not that rigid. Instead, it was more *vivid* and *concrete*, *easier to understand*."

> "If I just look at the equation, I have no idea of its meaning at all, because it is just in the textbooks. . . (After *doing* this activity,) I felt it was *realistic*."

> "There was an opportunity for us to imagine. We *generated our ideas* and had a deeper impression of acid and alkali, which became easier to remember."

> "I learnt quite a lot, because I could *look for the answer by myself*. I found that these activities could help students to obtain more knowledge."

> ". . . I took the initiative to *discuss with my classmates* and *ask questions.* I used my brain to *think it over.* I had a better understanding of plants. . .."

> "Usually we *listen* to teachers' lecturing without *doing* it personally. . .. cannot have much understanding about the topic. Now I've got a better understanding."

Some students commented that gaining more knowledge was something like a "by-product" in doing this kind of activity, because they needed to read outside textbooks and completing the activities. "We were not allowed to use laboratory materials and had to find out the materials in daily life by ourselves. . .We thought a lot more. . . not only textbooks, and developed in other respects. . . gaining more knowledge." Another student stated that "I would have a better understanding, because you have to understand first before you could make it (in doing the creative learning activities). I have the initiative to read more too." One even reported that he learnt more as teachers taught less. "There were more activities than usual. . .. Perhaps we learnt fewer topics, but in fact more in-depth, so actually we could gain more." Furthermore, some students could come to explanations like "knowledge is easier to be absorbed if you can make use of it", and "it is easier to understand and more impressive if we come up with the ideas by ourselves". There was evidence that, through this creative learning experience, some students had learnt how to learn science knowledge in better ways.

4.3.1.2. Daily-life image towards science learning. Apart from gains in science content, quite a number of students described positive changes in their images towards science learning. Some students reported that, in before, they had the conception that science was abstract and remote, but now they discovered that science and science learning were more daily-life, practical and integrated. It seemed that this creative science learning experiences had provided more opportunities for students to explore science in daily-life, which they was lack of in their normal learning.

> "I took the initiative to search what chemicals exist in *daily life.* I found that quite a lot of things in *daily life* were related to chemistry."

> "Usually in other lessons, all materials were just from the books. This time, it was more *daily-life* ... Our group has mainly used soft drink and mentos. . .This time, we learnt that we could use materials in our *daily life* (to do experiments)."

> "I learnt that experiments could be done in such a simple way. The materials used could all be found in our *daily life*. It was not necessary at all to have any expensive or lab apparatus."

> "As we estimated the height, we thought about different ways. . . We learnt that actually physics knowledge could be *infused* into chemistry (activities)."

> "I see. What we had learnt were not useless! We even used physics knowledge (in chemistry activity). . . It took us a long time to discuss how to estimate the height (in the shooting of carbonated rocket). Finally we realized there existed resistance. . .really hard to estimate. . .but we could use the (Physics) knowledge learnt."

Quite naturally, having an active learning style, a more playful experience, and a more daily-life image of science, student interests in the science subject were enhanced. Students reported "My interest in learning (science) increased. . . more lively. . ..", and "I used my brain to think it over. . .. searching information about plant in daily-life. . ..I love biology more."

4.3.1.3. Biased towards understanding of science knowledge. The data from student interviews could be analyzed from another perspective. Five types of creative science learning activities, discovery, understanding, presenting, applying and transforming science content knowledge, were suggested to teachers for reform. From student interview feedbacks, this study found no obvious evidence on learning related to the fifth type of creative learning activities, transforming science knowledge. In contrast, many students considered their better understanding of science knowledge as their major learning outcomes. Students related this gain with their chance in discovering, presenting, and applying the science content knowledge. However, no students reported knowing how to discover and present science knowledge as their learning outcomes. Whereas, only two students mentioned that they learnt how to apply what they learnt in lesson to daily-life. They reported ". . ..it helped me to apply the knowledge outside the lessons", and "I will apply the knowledge learnt in this class to daily life. (It) has long-term effects". It seemed that students' major concern was their understanding of science knowledge and, to a lesser degree, its application.

In sum, science knowledge acquisition was mostly frequently reported by students as their major learning outcomes. Among the five areas, students concern the understanding of science knowledge most and the transformation of science knowledge least. Through the creative learning experiences, students gained deeper understanding and memory of science content knowledge, more daily-life image of science, more interest in science learning, and stronger view on how to learn science knowledge. These improvements were highly valued by the students, as they reported them as their major learning outcomes. These learning outcomes were not directly related with creative thinking abilities of students, and originally not included in the curriculum model described in Section 2.

4.3.2. Creativity-focused learning outcomes

4.3.2.1. Broader thinking. Echoed with the purpose of the curriculum design proposed in Section 2, quite a number of students feedback that they learnt to think wider and broader in more perspectives. This study found that students related these outcomes with the open-ended activities in which they were requested to generate large number of answers, to apply their science knowledge to daily-life events, to do experiments without laboratory materials, and to find alternatives to that in the textbooks. However, none of the students mentioned that their creative thinking abilities were enhanced or they became more creative after these learning experiences. Instead, it seemed that students had gained a conception of multiple possibilities and an appreciation of flexible thinking style.

> "I learnt the importance of creativity. Need to be multi-facets. I think from *different perspectives.*"

> ". . ... Sometimes, when I could not come up with an idea, I needed to *think from another perspective.* In the end, I used salt and carbonated drink (to make the carbonate rocket). In fact, at first, I was thinking of using the lab materials."

> "I learnt to take the initiative to find other information. Because using different materials lead to different results. I would *search for alternatives.* The more searching I do, the more I get."

> "I know if there is no pH indicator around, what I can use. . . I now think more, and spend much more time imagining. I know I need to t*hink on many aspects,* because I could not come up with good ideas if my thinking is not broad enough. I like thinking of beans, thinking of vegetables."

> "It used to have only one option. But now you could not find the answer from the textbook. For instance, making an analogy. When taking exams, we are asked to use ball-pen only. Why can't we use pencil? Using pencil also has its own advantages. It is easy to modify answers. Through these trainings, I learnt th*e multiple-perspective thinking style.* If you read books, it is for sure that they teach you how to use the chemicals according to their instruction. In fact, there is another way around. It also works with another chemical."

The above student feedbacks collected were related mainly to flexibility and fluency, that is, generating many ideas and from diverse perspectives. Meanwhile, very few of those feedbacks were related to development of novelty, imagination or synthetic thinking abilities. Students had not mentioned the seeking of original, novel or unusual ideas. Feedbacks like thinking into future, the unseen and the impossible, and thinking beyond the existing human understandings rarely appeared. Students' responses also did not reveal that they had learnt how to synthesize knowledge, skills, divergent and evaluative thinking together to produce new and useful ideas.

4.3.2.2. Creativity and its strategies rarely mentioned. For the metacognitive development, this study adopted the infusion approach for developing creativity in school. Teachers in this project were encouraged to teach students the creative thinking strategies and creativity metacognitively. However, this study found that, when asked what students had learnt, terms like brainstorming, metaphors, SCAMPER, CPS, synectics and forced association, were rarely found in student feedbacks. No evidence was found to support that students could describe or criticize the creative thinking strategies, or know how to regulate or transfer them. In interviews, only very few of the students mentioned explicitly their conception and understanding of creativity and creative thinking strategies. Here were all the descriptions of this kind collected in this study.

> "Creativity is something that has never been thought of by the predecessors... For instance, what was taught before in class was theories and principles... Creativity is actually *different from the regular.*"

> "I learnt the importance of creativity. Need to be *multi-facets*. I think from *different perspectives*." (repeated)[1]

> "Creative skills are *substitution and replacement*. No definition as to what creativity is."

> "Creative ideas sometimes just *flash in my mind*. We cannot force ourselves to have creative ideas. . . ."

4.3.2.3. Developing some preliminary personal strategies. In the interview results, instead of mentioning strategies taught by teachers, quite a number of students managed to provide some detail descriptions on development of their own personal strategies. Their common strategies of problem solving were characterized by these steps – seeking ideas from other students, books or world-wide web, and testing the possible solutions. However, the other systematic steps in the CPS model, including the mess-finding, problem-finding and solution-finding process, were absent. Here were some of their descriptions – "I had several ideas at the beginning...then tried them out one by one"; "I learnt that nothing would be successful upon the first attempt. You had to try several times. I also learnt different ideas from others. And, I explored from the daily life and discovered more new ideas"; "I had no idea how to do. Then I surfed on the internet. Later I listened to a song named Doraemon. I then tried to use this song"; and "... the activity that asked us to seek many answers and think about many possibilities. We eliminated some of them based on our prior knowledge and then try out those remaining ones" (repeated).

Apart from this problem solving method, out of 30 students, only four students showed evidence of developing other personal strategies in their creative thinking process. For example, one student managed to describe how he discovered the existence of his own incubation and illumination process in the solving problems, which was well-documented in creativity literature (Ribot, 1906; Rossman, 1931). He reported "...I know if there is no pH indicator around, what I can use. Creative ideas sometimes just flash in my mind. We cannot force ourselves to have creative ideas. In class, I could not come up with any ideas. But many ideas came up when I returned home. I think whether I could use vegetables or potatoes...". Another student described how she made intuitive guess, self-developed hypothesis and tested the hypothesis in her own way. "At first, I thought about things in categories. I was wondering whether the darker the color, the more suitable it was for indicator. Carrots have got sharp color. It turned out that there was no such relation. In fact, onions and plums could also work. There was much guessing in the process. I just pondered over them and did not test all of them." These feedbacks provided evidence that the creative learning had provided chance for some of the students to develop their personal thinking strategies, though the strategies described were rather simple and the number of students involved was very small.

Furthermore, the curriculum design proposed originally included the transfer of creative learning. However, in the interview results, only one student mentioned this kind of ability, "I learnt to solve a problem from different perspectives, and apply this (problem solving method) to daily life". On the whole, the metacognitive development in creativity and the transfer of creative learning of students were found to be weak, though there were signs of student preliminary development of personal thinking strategies.

[1] The script is being used for a second time, serving a different purpose of analysis.

4.3.3. Other learning outcomes

4.3.3.1. Developing curiosity and sensitivity in science. Results also indicated that some students were developing creative affects mentioned in Section 2. Some students feedback that they were now more eager to know things around them, and become more sensitive to science in daily-life. They reported "after this activity, I hope to know more things about daily life", "I now have the initiative to look around what chemicals exist in daily life", and "I learnt to observe different phenomena before making explanations. I became more concerned with things around me". These students were developing their curiosity and sensitivity in science.

4.3.3.2. More confidence in self-expression and self-learning. Quite many of the students feedback that they gained higher confidence, including confidence in speaking up, asking questions, discussing with classmates, doing experiments, finding data, self-learning, and becoming less shy and more brave in class. What students mentioned seemed to be some simple and basic attitudes in a science classroom. It was quite surprising to collect this kind of feedbacks as major learning outcomes from high school students. It seemed that, in the usual science lesson, students were lack of chances to express themselves, to communicate, to try-out their own ideas or even to do experiments themselves.

> "I learnt how to *communicate with others* and focus on the key points. I am *more confident and brave* . . ."

> "In addition, I learnt to be *braver*. I gained the communications skills and became *more courageous to discuss with classmates*."

> "I found that I could look for the answer by myself. If teachers just deliver the knowledge in textbooks, I don't know how to ask questions even when I don't understand. But now, I am *a bit brave and dare to ask*."

> "The lessons made me become *braver*. I started to become clearer about what I had no idea before. It trained me of self-learning. I had to think by myself, discuss with the teacher, read books and turn to others. My *confidence was built up*. I then knew how to get myself across to others. . ."

> "When singing, I felt a bit scared. But when I noticed the classmates and the teacher watching happily. . . applauding, I *no longer felt shy*."

4.3.3.3. Higher initiation in learning. In line with these feedbacks, a number of students further commented that they started to be aware of the limits of textbooks, and they should not rely on textbooks or teachers only. Many said that they would read more books outside formal curriculum. Some even reported that they were becoming more self-initiated and self-confident in learning.

> "We should learn by ourselves, rather than relying on teachers. We should *read more books*."

> "I would think a bit more. Usually we refer to text-books. Now, I would *turn to other resources*."

> "The lessons made me become braver. I started to become clearer about what I had no idea before. It trained me of self-learning. I had to think by myself, discuss with the teacher, *read books* and *turn to others*. My confidence was built up. I then knew how to get myself across to others. . ." (repeated)

> "I learnt to *take the initiative* to find data. Because using different materials lead to different results." (repeated)

> "(The teacher) did not mention how to think. He taught us to think by ourselves. No specific rules as to think in one way or another. All roads lead to Rome. It turned out that some ways were not quick enough. What books offer are standard answers. They would not provide you with less good methods (other than the best one) to solve the problem. I tried my best to *think out ways as many as possible*."

Though quite many students reported improvements in their curiosity in science, confidence and self-initiation in learning. However, students rarely mentioned that they gained higher confidence in voicing out unusual opinions or crazy ideas. Nor were they more confident in tackling novel or complex problems. Similarly, feedbacks like "strong desire to imagine or to make dreams" or "favoring high challenges or eager to take risks or challenge authority" were nearly absent. In fact, none of the students directly claimed that they had higher confidence in creative thinking, or greater desire to become a creative person. Though cultivating curiosity in daily-life science, confidence and self-initiation in learning might, to certain extent, facilitate students' development of creativity in science domain, this study found no direct evidence to support stronger student motivations and affects in creativity development, especially that at "high-order" level. Furthermore, though there were signs of some self-learning activities, however, evidence of students being allowed to control, direct, design and regulate their science learning in class was absent.

4.4. Learning outcomes perceived by students – questionnaire results

Besides the interviews, this study had conducted a pre-teaching and a post-teaching questionnaire to evaluate student learning outcomes. Compare-mean analysis (t-tests) on each individual item in the questionnaire was computed. All items which had shown significant changes after the creative teaching were reported in Table 2.

Table 2
Means, standard deviations, *t*-values and effect sizes of science-related items in the student questionnaire ($n = 246$).

Science related items	Pre-test		Post-test		*t*-test
	Mean	SD	Mean	SD	
Attitudes and concepts					
2.0 I feel that science is a bit hard to learn (reversed).	2.48	0.98	2.67	0.96	2.79**
2.1 I believe that everyone can become a scientist if he/she works hard enough.	3.25	1.16	3.41	1.07	2.09*
2.2 Science classes are suitable for the training of students' creativity.	3.25	0.91	3.52	0.81	4.35***
Abilities					
2.3 I master the way to make simple scientific inventions.	3.06	0.88	3.27	0.88	3.23***
2.4 I know how to present science in a nonverbal but lively way.	3.15	0.96	3.36	0.85	3.11**
2.5 I master the way to discover and test new scientific knowledge.	3.20	0.81	3.33	0.78	2.13*
Daily-life behaviors					
2.6 I ask others some novel science questions.	2.89	0.88	3.01	0.93	2.26*
2.7 I do some small experiments or tests at home.	2.23	1.00	2.50	1.04	4.03***
2.8 I take the initiative to know the stories of scientists and inventors.	2.50	1.08	2.66	1.02	2.16*

c $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

In line with the results in student interviews, the result of this questionnaire indicated that students had some significant improvements in their science learning, especially that related to creative science development. For changes in attitudes and conception, students had gained a better image of science after the creative science learning – science is easier to learn (reversed of item 2.0), everyone can become a scientist (item 2.1) and science class can train creativity (item 2.2). For changes in abilities, students responded that their abilities in making simple scientific inventions (item 2.3), presenting science in creative ways (item 2.4) and discovering scientific knowledge (item 2.5) were significantly increased. For changes in daily-life behaviors, students seemed to be more self-initiated in science learning – more likely to ask science questions (item 2.6), do small experiments at home (item 2.7), study stories of scientists and inventors (item 2.8). Again, no evidence relating students' abilities in transforming science knowledge was found.

For results on general creativity, rather unexpectedly, this study found that, after the creative learning experience in science lessons, students' image of creativity and attitudes towards creativity learning in school were significantly changed in the negative direction. Students were more likely to think that creativity or creative learning was rather a waste of time and not so important to their study (item 3.1–3.4). This result echoed with that in reported in next Section 4.3, students felt that the creative learning was wasting time and not useful to examination. It should be noted that the post-questionnaire was administered just before their final examination, and creativity was not assessed in the examination. More discussion on the reason of this negative result could be found in Section 5 of this paper (Table 3).

The result of the questionnaire also revealed that students had stronger conception that creativity was related to high IQ and exceptionality (item 3.5–3.7) after the creative learning experience. The fact was most students in this study had nearly no experience in creative learning before this project. As reported in the next Section 4.3, students felt that the creative activities were difficult and demanding, especially at the beginning. Students might find that creativity was not so simple

Table 3
Means, standard deviations, *t*-values and effect sizes of general creativity items in the student questionnaire ($n = 246$).

General creativity items	Pre-test		Post-test		*t*-test
	Mean	SD	Mean	SD	
Attitudes					
3.1 Those very crazy ideas are not especially appealing to me.	2.41	0.95	2.67	1.00	3.67***
3.2 Creativity is very important to students' future study and lives.	3.76	0.82	3.60	0.79	−2.61**
3.3 Not all problems can be solved. My effort in thinking may be wasted.	2.52	0.99	2.74	0.92	2.74**
3.4 Novel ideas are always not as useful as traditional ones.	2.56	0.97	2.76	0.94	2.80**
3.5 Creativity learning is a waste of time, without much effect.	2.6	0.95	2.73	0.94	1.78c
Concepts					
3.6 Only exceptionally smart persons are creative.	2.15	1.03	2.27	0.96	1.73c
3.7 Only persons of high IQ can have creativity.	2.22	1.01	2.41	1.03	2.59**
3.8 Creativity can only be found in great things, not in daily life trifles.	2.34	0.93	2.52	0.92	2.59**
Daily-life behaviors					
3.9 I appreciate and pay attention to creative person and things.	3.62	0.97	3.45	1.02	−2.07*

c $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

and easy, as they might assume when they had not yet had any experience in it. This new learning experience might build up or further reinforce their genius view of creativity.

Furthermore, opposite to the results in daily-life science behaviors (item 2.6–2.8), nearly all items on daily-life creative behaviors were either insignificant or in the negative direction (item 3.9). These results implied that the transfer of creative learning in science domain to general creativity was limited.

On the whole, the results of this quantitative study echoed with the absence of high-end creativity learning outcomes in student interviews, which were reported in details in the last section.

4.5. Problems perceived by students

4.5.1. Adaption problems

Though most students reported delighted feelings in the creative learning process, not all of them were positive towards this creative learning experience. Quite a number of the students had some adaptation problems. They felt bored, puzzled, lost or even a waste of time at the beginning, but some of their perceptions improved after engaging in the creative learning for some time. In fact, this study found that many of the students' feedbacks were not "one-sided". They included both negative and positive feelings on the creative learning. Most of them involved some kinds of dilemmas.

> "At first, I felt *bored*. Nothing inspired (me) to take the initiative. When it was time to do the experiment, I felt *happy* and *interested*."

> "At the beginning, I felt *puzzled*. Later, I took the initiative to discuss with my classmates and ask questions. I used my brain to think it over. I had a *better understanding* of plants, and love biology more." (repeated)

> "I was *reluctant* to do at the beginning, even at the time of writing up the proposal. It was out of my expectation that the rocket flied that high. What is more, the experiment was taken in the open space of the school canteen. I did have *a sense of achievement*."

> "At first, I thought it was *wasting time*. You see, we have examinations (ahead). But now I felt it was *worthwhile*. . .. so impressive to me."

4.5.2. Time constraint

Besides the need of adaption, several other problems were mentioned by students. A number of students feedback that the working time in lesson was not enough. Other students puzzled why the teacher wasted a lot of time in creative tasks, as they were not useful to examination. They criticized the activities as not practical (to examination), more like playing games (in negative sense), and making them learnt less (knowledge).

> "I won't expect this!. . . for instance, *time*. . ."

> "*Short of time*! It would be better if we had more time."

> "I was so happy, but it seemed unrealistic. Learning effectiveness seemed not so high as it *used up much time*. The chemistry lesson has a tight schedule."

> "My interest in learning was improved. . . lively. . .relaxed. . . playful. . . I like that. But it was restricted by *exams*. . . and *time*." (repeated)

> ". . .usually, not that many activities. We often learn what is useful for exams, something more practical. These were *not that helpful*. Usually we aimed at exams and had lessons according to that syllabus, these activities were just games, not useful for exams. They are useful only in daily life, for *playing and entertaining*. . .. . .but these activities could enhance my knowledge. The class was also relaxed, not under great pressure as usual. Perhaps we *learnt fewer topics*, but in fact more in-depth, so actually we could gain more." (repeated)

4.5.3. Creative thinking and activities are demanding

Other students might not be used to classroom tasks which required high-level thinking. They felt that the creative learning was troublesome, abstract, difficult and demanding. Other students revealed that they did not have confidence in the unfamiliar tasks, like making songs, drama, and they lacked of the specific skills to complete them. However, many of these students gave more positive feedbacks after completing the tasks or sharing in classmates' presentations.

> "The teacher keeps asking questions, which are usually very *vague*."

> "At first, I felt *troublesome* because we had to find the material in our daily life. So I did not want to do it."

> "In fact, it was a bit *difficult*. . . I learnt that before. . .How to help myself? I encouraged myself to read books. It could also help me to memorize."

> "It was *hard to create a play*. You had to make use of what you had already known in mechanics. Yet, what you have got to know in mechanics may not be daily-life. Then you had to think it over and over. Perhaps not all the physics

materials would be used. Selecting material was *so difficult*. We might have such daily-life experience, but we do not know that it embodies some physics knowledge."

"It was *difficult* to find the right song as there should be a rhyme. Besides you have to write words with principles of Heat. At first, I thought it was easy. But gradually, I found it was *difficult* to get the words. Since I was not good at music, I had no idea how to do. Then I surfed on the internet. Later I listened to a song named Doraemon. . ." (repeated)

4.5.4. Suggestions for improvements

When asked any suggestions for improvement, students indicated preferences which might be overlooked by teachers. Some students hoped that teachers could facilitate their learning by giving them more examples, more working time and relating examination content more with daily-life. It seemed that students felt that these three elements were inadequate in their lessons.

"Short of time! It would be better if we had *more time*." (repeated)

"I found that chemistry is rather abstract. The teacher could *give more examples in class*."

"It would be more impressive and clearer if the *examination content could be infused into daily-life examples*. If it is not applied to daily life, then it would be difficult to remember. . ."

4.6. Summing up of results

On the whole, the results of the qualitative and quantitative studies in this study converged and provided substantial evidence to some conclusions. First of all, after the teachers infused creativity learning elements in their regular science classroom for several months, there was evidence of improvements in student conceptions, attitudes, abilities and behaviors in creative science development. Most students perceived some significant changes in their classroom learning. They characterized this creative learning as active and playful, encouraging them to think boarder and wider, appreciate creative ideas, developing their curiosity, confidence and self-initiation in science learning, enhancing better understanding of science knowledge, and more daily-life image of science. However, in comparison, students were putting much stronger emphasis on their learning of science subject content, rather than that of creativity. Results indicated that, developments in general creativity, including its related affects, thinking abilities and strategies, was quite limited. Those reported creative outcomes were mainly the lower-end ones, whereas high-order ones like risk-taking, challenging authority, transformation of existing knowledge, novel and synthetic thinking, complex CPS strategies, metacognitive development, transfer, self-control and self-regulation of learning were rarely found. Students' tensions and dilemmas reported mainly came from the change in learning style, time constraints, knowledge-orientated examination, high demand in thinking, lack of task-specific skills, and etc.

5. Discussion

In regard to an *Eastern* educational context, this study explored how to infuse creativity elements into regular science lessons of Hong Kong. It started off from a comprehensive curriculum redesign model which included some common creativity learning objectives and teaching strategies found in *Western* literature. It then invested tremendous efforts and took a long process to train up a group of interested teachers, and supporting them to implement this creativity-infused curriculum in their own ways in their regular science lessons. Apart from the additional teacher training, the implementation process of this curriculum reform highly resembled that in normal school contexts of Hong Kong. As a result, the findings of this study reflected at least part of the realities and constraints in the educational contexts of Hong Kong, and shed light on creativity reforms undergoing in similar Asian places. The followings are the implications and contributions of this study.

5.1. General picture of infusion approach in creativity education

On the whole, the infusion approach of creativity education adopted by this study had successfully improved students' abilities, attitudes and conceptions in creative science development. Evidence of creative learning through activities on discovery, understanding, presentation, application of science content knowledge was found both in the quantitative and qualitative studies, though transformation of science knowledge was rare. The method described in Section 2.1 was found to be a useful method to infuse creativity learning elements into science subject content.

The creativity development evidenced in this study was more *domain-specific* than domain-general in nature. First of all, knowledge and positive attitudes of a domain are fundamental ingredients of creativity development in that specific domain (Amabile, 1989; Craft, 2005; Weisberg, 1999). Therefore, the gain in science content knowledge and science image in this study were expected to be beneficial to the creativity development of students in science. Moreover, the quantitative study found that all four aspects of creativity development in science, its attitudes, conception, abilities and daily behaviors, were significantly increased, whereas no similar positive results were found in general creativity development. In the interviews, students' creative learning outcomes were also more related with science than with general creativity development. The nature of infusion approach might play a role in explaining this domain-specificity of results. It surely would impose constraints on the transfer of creative learning to general domains. Maybe, as commented by Kaufman and Baer (2005, 2008), creative learning infused into school subject curriculum is inevitably more domain-specific. In the government educational policy of Hong Kong, creativity is documented as a generic skill to be developed across the curriculum. There are little existing theories and research informing educators how creative learning in one subject domain can be transfer to another domain effectively in school contexts. More curriculum studies are in need to answer this domain-specific versus domain-generality question.

Interestingly, in this study, efforts aiming at fostering student creativity ultimately benefit students' knowledge learning. Instead of creativity development, most students emphasized gains in their understanding and memory of science knowledge, and their positive image and attitudes in science learning. These positive learning outcomes might be related to the active and playful learning style reported by students. Student feedback indicated, through the creative learning, they engaged in deeper processes of content knowledge and also felt a higher need of learning science, and, as a result, student gained better understanding and memory of the science knowledge. This result echoed with Conti, Amabile, and Pollak's study (1995) which found that creative activities enhanced memory of students. Though active and playful learning style might not necessarily implied creative thinking, it did bring about some positive learning experience, which were well-received and valued by students in Hong Kong. This finding aligned with the comment of some creativity scholars. Starko (2010) commented that teaching that supports creativity also supports good content teaching. "Teaching that has the goal of increasing student creativity is also likely to benefit students by simultaneously promoting other kinds of learning, including the acquisition of content knowledge" (Kaufman & Baer, 2008, p. 27). The result of this study encourages educators to hold a broader view on the purpose and content of creative learning and teaching. It serves not only creativity development of students, but can be considered as a progressive form of education which benefits student learning in multiple aspects.

5.2. Contextual and cultural characteristics of creative learning

Referring to the creativity curriculum model (in Section 2) which was developed based on Western literature, findings of this study revealed that not all learning objectives of it were achieved. In simple words, the final creativity development of students in this study was not at the same level as what was depicted in it. It was evidenced that some elements in this suggested curriculum design could be more readily achieved and recognized by students, whereas others might be harder to implement in this context. In this regard, the school-based creativity education, which adopted infusion approach and contextualized in Hong Kong, had its unique characteristics. This study revealed that creative learning was not universal over the world, therefore, no single creativity curriculum model suites all places, subjects and cultures.

The creative learning found in this study had strong *contextual* characteristics, including that related to local educational systems and science teaching. Like many Asian places, the education system of Hong Kong is well-known to be rigid and highly-centralized with curricula heavily loaded with didactic knowledge. Especially in senior levels of secondary science, learning is dominated by scientific theories and facts, accurate and fixed answers with no room of ambiguities. Teachers and students are very examination-orientated. The public examinations of secondary science subjects in Hong Kong are dominated by questions on rote-learning, whereas open-ended questions and creative thinking elements were nearly absent. In this study, students' descriptions of their previous learning styles and their subsequent changes were consistent with these characteristics of Hong Kong context. The learning outcomes reported by students had put a strong emphasis on the acquisition of content knowledge and the requirements of the examinations, because they not only reflected what they had learnt, but also what they valued in the learning process.

These contextual characteristics had given rise to some of the tensions and dilemmas mentioned by the students, for example, the lack of working time and the waste of lesson time. They were in fact the two sides of the same coin. As the content of the curriculum and the public examinations cannot be changed by individual teacher or school, therefore, in infusion approach of creative teaching, teachers need to cover the same science knowledge content as before. Resembling the city-wide educational reform in Hong Kong, the teachers of this study were given no additional resources. In fact, like many places in Asia, school science curricula of Hong Kong are already very heavily loaded. The teaching schedules of most schools are originally very tight and leave very limited room for anything extra. If, in case, teachers felt that the predesigned knowledge content in the original curriculum could not teach effectively through the creative activities they "added", most teachers used to teach the knowledge back in some after-school hours. Of course, most students disliked this arrangement. This might be one of the major reasons why student conceptions on creativity and their attitudes towards creativity learning in school (reported in Section 4.2.2) were less positive after the implementation period. This study informed educators that, though infusion approach was adopted, creativity learning still needed additional resources, especially time.

The results of this study also revealed that creative learning was cultural-embedded. With its collectivistic and Confucian root, traditional Chinese classroom culture was well criticized on its conformity, authoritarian and didactic approaches in teaching and learning (Cheng, 2004a; Leung, Au, & Leung, 2004; Ng & Smith, 2004a, 2004b). Student feedbacks collected in this study had clearly reflected the classroom reality in this culture and the difficult starting point of its creativity reform. Students of this study experienced hardships in the open-ended questions which required imaginative or novel answers. They got loss and confused, and felt that the activities were demanding, especially at the beginning. In fact, maybe partially due to this reason, students had a more genius and exceptionality view of creativity after this creative science learning experience. In asking what were their major learning outcomes, students claimed that they became less shy in speaking up (instead of voicing out unusual ideas); students claimed they now had more confidence in asking questions (instead of dare to challenge the norm or authority); students reported more freedom to express themselves and more self-initiation in finding data and reading other books (instead of signs of student ownership and control of their own classroom learning). It seemed that regular science classroom in Hong Kong was not so playful, open and daily-life. Students were not used to speaking up and asking questions in class. Nor were they used to reading books and finding data themselves outside classroom. After this study, though students had some improvements, it seemed that they were still far from voicing out unusual ideas, challenging the authority, or deciding on their own what and how to learn, which were documented as key elements of creative learning in some Western literature (Craft, 2005; Jeffrey & Craft, 2004; NACCCE, 1999, p. 92). In fact, instead of resembling that described in Western literature, the creative learning found in this study is simply a kind of liberation of traditional science learning, which is characterized as more active, playful and daily-life.

In further analysis, the creative learning emerged in this study demonstrated several typical cultural characteristics of Hong Kong (as found in Hofstede's cross-cultural study described in Section 1.6). As differentiated by Kirton (2003), there are two creativity styles, innovators and adaptors. Innovative creativity is associated with taking risks and pursuing more radical changes (i.e. doing things differently), whereas adaptive creativity aims at seeking methods and improvements in the given direction (i.e. doing things better). If analyzing the learning outcomes of this study in this dimension, its creativity-infused teaching had more likely fostered adaptive creativity rather than innovative creativity, because novelty, risk-taking, challenging authority and transformation of existing science knowledge were nearly absent in student feedbacks. On the other hand, student emphasis on understanding and application of existing science knowledge, together with generation of more alternatives in thinking, more confidence and initiation in learning all seemed more related to development of adaptive creativity. This result aligned with the findings of Puccio and Gonzalez, who after years' of creativity training in Asian places, concluded that adaptive creativity was more endemic to Asian cultures (Puccio & González, 2004). Why so? Lubart (1999) and Rudowicz (2004) suggested that Eastern concept of creativity tends to put less emphasis on originality and novelty, as compared with that of Westerners. Maybe, teachers' concept of creativity in this study also had this characteristic. As a result, creative learning reflected in students' feedbacks was biased towards the adaptive side. From another perspective, this adaptive characteristic of creative learning can be understood as an outcome of a culture with strong hierarchy of power and relationships. In a high power-distance culture, usually superiors set the goals whereas other people develop methods to achieve them. Innovative creativity belongs to superiors, whereas others only need to develop adaptive creativity. Though Hong Kong is a highly modernized city which has experienced a long British rule, it seems that the influence of traditional Chinese culture is still great.

Another interesting point revealed by this study was that, though students found the creative learning more active, playful and has higher self-satisfaction, they seemed not too value the creative elements in it. And, though students were engaged in discovery, presentation, application and to certain extent some transformation activities (see Appendix A), however, they simply considered them as means to improve their understanding of science knowledge. Why so? As a famous Chinese saying goes, "Diligence has its reward. Play has no advantage" (extracted from a well-renowned ancient Chinese text Three Character Classic). Obviously, playfulness is not so much value in Confucian teaching than that in Western education. As commented by Hennessey (2004), it is still not sure whether the intrinsic motivation principle of creativity is also applicable to the Eastern societies. Explaining from another perspective, Hofstede's study (2001) revealed that the "long-term orientation" dimension of Hong Kong had exceptionally high ranking (scored 96 out of 100). This is also a tendency of most Far East Asian cultures. In long-term oriented societies, people value actions and attitudes that affect their future, more than that affect their presence. They are determined to work through hardships in pursuing a future goal. In Hong Kong and many Asian places, students learn from a very young age that their goals are to get good examination results so as to enter a good university and pursue a high rewarding career. This clearly explained why students in this study valued content learning much more than creativity, which seemed not so directly related to their future goal. Asian governments and educators need to note this point carefully in promoting creativity reform.

Puccio and González (2004) further commented "the most efficient way to express one's creativity is to take advantage of one's innate tendencies and talents, and to not force oneself to behave in a manner that is inconsistent with those natural inclinations" (p. 420). In studying creativity reform in kindergartens of Chinese cities, Vong (2008) found that Western orientated pedagogies would not be directly transplanted by teachers, but was interpreted and transformed in ways that were consistent with the Chinese social and culture values, and those in conflict with the local cultures would be finally rejected. Echoed with these studies, result of this study further supported that cultural factors might play a significant role in shaping the creative teaching and learning in classroom. Contextual and cultural factors had exercised significant filtering effects in the top-down educational policies and curricular reforms.

5.3. Recommendations for creativity education in the East

With the existing cultures and contexts in Asian places, it was indeed difficult for their teachers and students to transform their usual passive and rote-learning type of lessons immediately into the one that had high level of novelty, imagination, risk-taking, complex synthesis, metacognitive development, student control and ownership. In light of the result of this study, educators should seriously consider the need in scaffolding various creativity learning objectives and activities into different levels, from adaptive creativity to innovative creativity, that is, from simple creative attitudes, thinking abilities and thinking strategies to those high-order ones. Decades ago, Taylor (1975) already proposed the existence of different levels of creativity, from purely expressive and productive to inventive, innovative and emergent creativity. However, similar kind of level building in creativity education was still not well-documented in education literature. Looking forward, educators may need to develop a method to differentiate, define, teach and assess different levels of creativity in school education. A step-wise creativity education models which suit the specific cultural needs and educational systems of different Asian places were called for.

Apart from adjusting the reform strategy to suit the local context, educators should also try to reshape the school culture and educational systems to realize creativity reform. For example, education policymakers and leaders need to consider reducing the heavy knowledge-content of the curriculum, improving assessment methods to include creativity elements, providing more teacher professional training on creative teaching, and allocating more resources to creativity reform. In parallel, teachers should dare to surrender the comfort zone, take sensible risks and make breakthroughs with their students in creativity pursuits. On the way to embrace the era of creativity, all Asian educators need to work hard in this direction, evolving a new culture in the East.

5.4. Towards student-inclusiveness in creativity reform

Creativity education was imposed by Asian governments for the purpose of increasing competitive power of nations. This kind of educational reform has a danger of putting too much emphasis on product-based and high-end achievements, and not fully addressed the basic development needs of students in the conventional local contexts. This might be one of the reasons why in recent years there were many progressive educational reforms in Asian places, but most met with obstacles. Many policies of this kind cannot be successfully implemented or the changes cannot sustain. Asian governments used to adopt a top-down approach in developing their educational policies, and student voices were nearly completely absent in the hierarchy. Most Chinese adults tend to think children do not have the abilities to understand what and how they learn, nor can they make sensible advice on it.

However, this study had shown that secondary students were capable in giving meaningful feedbacks on their creative learning. They could describe its differences, spell out their preferences, and what they had learnt and valued in the process. In this study, students characterized creative science learning as those involving playful science activities and experimenting with daily-life materials. In students' view, creative learning was a kind of active learning which gave them more chance to actualize themselves, and to think wider and boarder. In this learning process, students valued the gain of more knowledge, deeper understanding them, and its application in daily-life. Students appreciated their interest on things around them, also their growing confidence and self-initiation in learning. Though student feedbacks are usually simple and straight-forward, they, down to the earth, reflect their own learning desire and needs. These student feedbacks may be one of the most useful sources of information, informing teachers, schools or policy makers what should be the first step of change in their ambiguous plan of reform.

In future, voices of all stakeholders including that of students should be involved. Academic field are in need of more student-orientated studies, looking at what was really happening in the classroom from students' perspectives, what were students' needs and preferences. Meanwhile, students themselves also need to reflect on their own creative learning, as they get involved in the process of creativity educational reform. An inclusive education reform, with both the participation of students and educators in the change process, is called for in Asian place.

5.5. Limitation

Most data of this study were collected by survey questionnaire, interviews, with a part from pre and pro-tests. In usual practice, comparison groups would be ideal for analyzing results of pre and pro-tests. However, in consideration of the large scale of the project (more than 30 schools and 30 teachers), comparison groups may not be so feasible and significant. Findings of this study were validated by triangulation method. The qualitative and quantitative results were found to be consistent with each other, whereas the student characterization of creative learning echoed with their perceived learning outcomes. Therefore, no additional evidence from other sources was further sought. After all, this study targeted at understanding creative learning in specific contexts, rather than finding isolated cause-and-effect relationship. In fact, the contextual design of this study allows us to discover the contextual characteristic of creative learning, whereas the subject-based design reveal the domain-specificity of creative learning. Without adopting this research approach, these significant results may not emerge.

This paper is not an East and West comparison study. It only aimed at understanding the characteristics and outcomes of creativity reform in a Chinese society situated in the East. Of course, the results of a study in Hong Kong cannot be directly generalized to all Eastern societies. Several studies (Rudowicz & Yue, 2000; Yue & Rudowicz, 2002) showed that Chinese and Asian societies did have some variations in their creativity-related concepts and perceptions. However, as commented by Niu (2006), there is significant difference between East and West culture in relation with creativity reforms. Hofstede's study (2001) suggested that Hong Kong's cultural characteristics resembled that of Asian or Chinese societies, rather than that of Western societies. It has a high level of emphasis on collectivism, power-distance and long-term orientation. The results of this study do highly echo with these cultural characteristics. This study improves our understanding of creative learning in cultural perspective, and shed light on creativity reforms in other Asian societies with backgrounds similar to that of Hong Kong.

6. Conclusion

To realize creativity education in school curriculum, finding methods to integrate creativity learning and that of content knowledge is unavoidable. Obviously, it is not an easy task. In the process of integration, adjustments, balancing and compromise between the two learning domains are expected to occur. This study provided one potentially useful method for infusing creative learning into subject content, including the discovery, understanding, presentation, application and transformation of content knowledge. The results of this study highlighted several important directions and factors for Asian educators to consider when infusing creativity learning into their regular lessons. They included the perceptions, needs and preferences of students, their tensions and dilemmas in the learning process, the heavy cultural and contextual influences and also the domain-specificity of the infusion approach of creativity education. In future, education policy makers need to note that the starting points of creativity reforms in Asian places may be quite different from that of some Western countries. Simple direct transplant of Western style of creativity learning and their pedagogical practices would surely meet obstacles. In light of this study, it seems that an active, playful, self-actualizing learning style, which emphasizes deeper understanding and daily-life application of science knowledge, and, at the same time, encourages creative appreciation, alternative thinking, curiosity, confidence and initiation in learning may be more readily implemented in schools and favored by students in the existing Asian contexts. In light of this study, Asian educators should consider scaffolding creativity education into various dimensions and progressive levels, with higher focus on adaptive creativity in its initial stage of reform, and the inclusion of student voice in its process of change.

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Appendix A. Creative science learning activities designed, implemented and reported by teachers

Free questioning (*discovery*)	A flask of water/a glass prism/a Newton's cradle/microscopic world is shown, and students question freely around it. Suggest questions around light-directedness of plant/around a pangolin (picture of the animal shown).
Free association, seeking multiple examples and ideas (*understanding*)	Create a mind-map around EM spectrum. Suggest multiple examples of "light-emitted" object/"wastes"/multiple uses of sea water/multiple methods for contraception/cooking/multiple characteristics of future battery/multiple negative impacts if wild animals extinguish/positive impacts of drinking coca-cola.
Suggesting analogy/metaphors, Creative writing with personal analogy (*understanding & presentation*)	Suggest analogies for acid and alkaline/emulsifiers/negative and positive feedbacks in biological systems. Suggest the similarities and differences between refraction and dating/acid-alkaline and woman-man. Write a creative story starting with "I am a light ray from the sun. . ."/"I am a module in a water wave. . ."/"I am a photon. . ."/"I am an electron in an electric circuit. . ."/"if I am an oxygen atom. . ."/"if I am an acid/alkaline. . .". Write a story on "hateful happiness of a piece of iron"/"the daily-life of hydrogen atom"/"Mr. sperm and Miss ovum". Suggest personal analogy of the particle model.
Finding problems, changes, patterns (*application*)	Identify the correct and incorrect optical phenomena shown in laser swords in science fictions/wave phenomena found in Chinese Kung Fu films. Identify possible sources of errors in this experiment/in this system. Identify all possible problems from this newspaper cutting – workmen found fainted in a dredge pipe. Discover any special scientific phenomena in observing this beaker of water.
Free guessing/free explanations (*application*)	Guess why the nails do not fall down/why the electric bulb does not light up in this experiment. Guess why images disappear when water is added (in a Physics magic show)/why the color changes in this magic show (chemistry). Guess why burnt food can conduct electricity/chlorine is highly reactive. Guess the use of this vitamin/nutrition/tropism (biology).
"what if"/making predictions (*application & presentation*)	What happens if every person has an optical fiber in his/her body/if 1 day, I find my hands can generate electrostatics/if Hong Kong is attacked by salt tide/if the world has 50% less oxygen/if there is no emulsifier/no water/no oxygen in this world/if human can change genes. (Some of these activities asked students to write a story on this what if situation.)
Cross-discipline/MI activities (*presentation & application*)	Create a song on heat phenomena and concepts. Create a new "The Tortoise and the Hare" story with concepts of acceleration, velocity, and displacement in mechanics. Write a story on a trip inside respiratory system. Write an autobiography of a salmon sushi. Create a drama on our daily-life with Mechanics concepts integrated. Role-playing particles in chemical reactions.
Making models/hands-on work/competition (*application & presentation*)	Making heat-insulating cup competition/Making parachute competition/Making highest rocket competition (physics)/Making carbonate rocket (chemistry)/Making soap with daily-life materials/Making water filtering device.

Suggesting new designs (not making models) (*application*)	Suggest multiple bridge designs with chopsticks. Design a cold-keeping box/an auto-heating food box with chemicals/a bag for snowskin mooncake. Design new anti-fake label for money note of Hong Kong. Add or eliminate safety measures/devices for science laboratory. Design a new ecological zone and its tour for Hong Kong. Make a construction plan.
Suggesting new scientific inventions (*application*)	Forced association of a “bed” and “eddy current”/“sense organs” and “helmet” to make a new invention. Apply SCAMPER to make a new invention, and present it in artistic drawing (art and science subject cross-disciplinary activity). Apply SCAMPER to create new designs of “healthy” overcoat. Suggest crazy inventions with the use of memory metal. Suggest new toilet/baby car/robot inventions with the use of metals. Apply adding and eliminating strategy to make invention around “water”/a new polymer. Invent a new living species with special kinds of competence, using rearrangement/recombination strategies.
Inquiry/experimentation (*discovery*)	Suggest multiple hypotheses for causing tooth decay. Suggest multiple methods for creating artificial rain/collecting gas from breathed air, in laboratory. Suggest multiple methods to test a CPU cooling device/whether something is a living thing. Suggest multiple methods to test two under-wears to see which one is “better”. An investigation on the properties of heat-insulating cup and barbecuing fork (physics). Investigate and find out what is the material put inside the mooncake box for keeping the snowskin mooncake longer. Open inquiry project on grass-hoppers/in chemistry/in biology (students design their own research questions and investigation methods).
Problem solving (*application*)	Suggest multiple methods to improve the function of a solar energy plate/cooling device in machines/hamburgers of MacDonald's/our breathing system. Problem solving activities started with: a global warming related news-cutting/if we lose our glasses/if no plastics in the world/all plants disappear/how to whiten the plastics cases of electrical appliances/how to prevent apples from changing yellow/how to remove chewing gum/how to transport water without aids/choose a daily-life problem.
Seeking alternatives/new directions (*application & transformation of science knowledge*)	What happens if objects expand when cooled, and contract when heated/if actions have no reactions/if atom has an additional 2p obit. Suggest adding and/or eliminating a heat transmission method/a chemical element/a factor influencing the resistance of resistor in an electrical circuit, and imagine what would happen.

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