Developing Physics learning activities for fostering student creativity in Hong Kong context

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Contents

Abstract

Though recent curriculum reform of Hong Kong, Mainland China, and Taiwan all include creativity as one of their major learning objectives, however, creativity-enhancing teaching methods are seldom implemented in real classroom practice. This study presents a systematic method for designing Physics learning activities for fostering student creativity in traditional educational context, like Hong Kong. It suggests a comprehensive set of learning objectives, strategies for generating new activity designs, and rationales for selecting activities, and more than 20 different kinds of learning activities that are simple and easy to be infused into normal Physics lessons. To understand teachers' and students' opinions on these activities, they were tried-out in two secondary classes, and were introduced to 120 senior Physics teachers of Hong Kong. On the whole, teachers and students gave positive feedback and support the usefulness and suitability of this set of instructional designs. Results also revealed some obstacles in fostering creativity of Hong Kong students and some shortcomings of these activity designs.

Literature Review

Basic concepts of creativity

Creativity is a complex and diverse construct. Recently, academic fields tend to have consensus on a multi-dimensional and multi-facet approach in defining, enhancing and assessing creativity. Creativity is believed to be a combination of abilities, skills, motivation, attitudes and other factors (Ripple, 1999). Even so, the most popular techniques for enhancing creativity over the past 50 years have involved the teaching of divergent thinking and general problem-solving heuristics (Plucker and Runco, 1999). The core components of divergent thinking are fluency (generating a large number of ideas), flexibility (generating ideas of different categories or approaches), novelty (generating unusual or rare ideas) and elaboration (generating ideas in detail) (Torrance, 1990).

In recent decade, there is a growing number of literature that concerns not only divergent thinking, but the integration of divergent and convergent thinking in the productive thinking process (i.e. producing new and useful ideas) (Treffinger, Isaksen, and Dorval, 1994). Instead of focusing on problem solving, studies also recognize the importance of problem-finding and sensitivity in the creative process (Runco, 1994).

In affective aspects, William's Taxonomy of Creative Thought (Williams, 1980) suggested that curiosity, imagination, challenge-taking and risk-taking attitudes are conducive to creativity development, and motivational factors, like interest, confidence and value in creative thinking are also important determinants. Amable's studies (1996) emphasized that intrinsic motivation on the tasks and playful attitudes facilitate the emergence of creativity. Some creativity-enhancement programs also involve the learning of specific idea-generating heuristics, like brainstorming, mind-mapping, forced association, check-listing, creating metaphors, creative dramatics (Starko, 2001). Among them, brainstorming technique, creative problem solving technique (CPS) (Treffinger, Isaksen, and Dorval, 2000) are most widely adopted in creative learning activities.

While the above mentioned scholars concentrated on the general aspects of creativity, some scholars believed that creativity is domain-sensitive (Baer, 1999). The former might believe that there exist a set of general creative attitudes and abilities that influence individual's creative behaviors across domain, and, through nurturing them, the overall creativity of a person can be enhanced. In contrast, the latter suggested that training in creativity cannot be transferred across domain. Whether creative activities in science can enhance some general attitudes or abilities of students, or merely creativity in the science domain involved, it is still an unanswered question. (In this study, infusing creativity-enhancing elements into Physics learning is assumed to have dual purposes.)

Creativity studies in science education

Many scholars have suggested that creativity development is inherited in scientific processes. Craft (2000), Loehle (1994), Meador (2003), Pye and Sherborne (2001), and Schamel (1992) considered engaging students in the active thinking in the open-ended scientific discovery and inquiry process as means to foster student creativity. Instead of asking students to follow a fixed set of directions in doing experiments, educators encourage students to form their own hypotheses and develop their own experimental designs. This open-inquiry approach is considered as a fundamental way to foster creativity in science, and is most widely incorporated into creativity-enhancing course in science education.

Besides this open-inquiry approach, problem-solving activities are always included in science learning curricula to elicit creativity. Two common structured approaches are the creative problem-solving (CPS) model (Treffinger, Isaksen, and Dorval, 2000), and the problem-based learning method (Gallagher, 1997). Abell (1990) illustrated how teachers can adopt the six stages of CPS strategies systematically to solve a biology ill-structured problem. Other educators (Gallagher et al., 1995; Krynock and Robb, 1999; Plucker and Nowak, 2001) suggested problem-based learning developed in science-society-technology approach as a most effective way to foster creativity in science. These instructional designs ask students to do projects on real-life ill-structured problems in a rather self-directed and systematic mode.

Besides the widely accepted scientific inquiry and problem-solving learning activities, educators have tried to integrate some common creativity-enhancing methods (most of which were originated from gifted education field) into science learning. McCormack and Yages (1989) proposed a new taxonomy of science education. On top of the common domains of science education (knowing and understanding, exploring and discovering, feeling and valuing, using and applying), they included an "imagining and creating" domain. They stated that "*the abilities that make up this domain are visualizing or producing metal images; combining objects and ideas in new ways; producing alternate or unusual uses for objects; solving problems and puzzles; fantasizing; pretending; dreaming; designing devices and machines; and producing unusual ideas.*" (McCormack and Yages,1989, p.48) In a following study, Gilbert (1992) suggested six kinds of questioning that should be involved in this creativity domain of science education. They are questions on association, imagination, brainstorming, organization, analogy and metaphor, and reconceptualization.

Though there are a number of isolated papers suggesting some specific instructional strategies for developing creativity in science learning, however, a complete set of activities for infusing creativity-enhancing elements into school science education, especially in senior secondary science curricula, is not yet known. In fact, quality science learning should involve a rich, wide and balanced selection of creative activities in their lessons. The first aim of this study is to develop a comprehensive set of creative science activities that are of wide coverage. This will serve as a checklist for science educators in designing creativity-fostering lessons. Physics is a chosen domain of science learning in this study.

Context

Chinese context

Recently, governments of Hong Kong, Mainland China, Taiwan, Singapore and other Asian countries have imposed rapid curriculum reforms in their primary and secondary schools. In the reforms, creativity development is included as one of the major new learning objectives. In Hong Kong, creativity is now one of the three most significant generic skills across all subject curricula. However, suitable instructional methods for fostering creativity, especially that in science subjects of high forms, are not known.

In fostering creativity of students, Hong Kong suffers nearly all the constraints that a typical Asian place has. Our school culture is highly competitive, examination-oriented, and its learning is dominated by extrinsic motivation. Both teachers and students are used to rote-learning and expository teaching. The workload of teachers is heavy, and most of the teachers adopted a textbook approach in teaching. The schools have large class size (of around 40), lack of resources and physical space, a rigid time-table and offer nearly no choice of subjects (except that between art and science stream).

Hong Kong has a rigid and heavy core curriculum, and two important public examinations in senior secondary levels. Among all school levels, teaching and learning at senior secondary levels are most examination-orientated. The senior secondary Physics curricula focus mainly on the acquisition of concepts and knowledge, and applying them to solve numeric problems. The Physics examinations seldom involve open-ended questions, and creative thinking is nearly absent.

Nearly all Physics teachers in Hong Kong have little creative learning experiences in both their school learning and teacher training programs. Though the educational reform is induced, most teachers in Hong Kong have not yet received any re-training in creativity. Their understanding and aspiration in creativity are very limited. In Hong Kong, like in other Asian places of which governments impose rapid curriculum reform, the operational or implemented curricula schools have great discrepancies from the formal or intended curricula. Due to the lack of monitoring in curriculum implementation and the lag-behind of reforms in assessment methods, teachers of

Hong Kong have no strong incentive to induce changes to their teaching.

Besides the constraints in the educational system, Hong Kong has a strong Chinese culture of collectivism that treasures conformity, discipline, obedience and authorities. In a large class size, teachers extremely concern about classroom discipline. Most of them cannot tolerate free talking and movement, or any kind of disorder in their classrooms. In the traditional Chinese culture, people mostly believe that basic skills and knowledge are important, and should precede creativity development. They appreciate children's serious effort in learning, and consider playful attitudes to be harmful to learning. Several educators suggested that these cultural factors may be detrimental to the creativity development of Chinese students. (Biggs, 1996; Cheng, 2004; Gardner, 1997; Watkins, 2000)

Approaches adopted by this study

There are several approaches for teaching thinking. First approach is characterized by direct instruction of thinking in non-curricular contexts. Students learn how to use explicit thinking strategies outside the standard curriculum. In western countries, there are quite a number of these pull-out creativity programs, in which some of them involve science elements. They include the Productive Thinking Program, Purdue Creative Thinking Program and Future Problem Solving Program (Cropley, 1999; Plucker and Runco, 1999; Ripple, 1999). Second approach employs methods, which promote thinking in curricular contexts. The tasks are content-oriented, and their goal is usually to yield a deeper understanding of what is being taught. No thinking strategies are taught explicitly. Third is the infusion approach, in which content lessons are restructuring for direct instruction in thinking skills and processes (Swartz, Fisher and Parks, 1998). The approach taken by this study is similar to the second approach. It is content-oriented, but the thinking activities go beyond yielding a deeper understanding of the content. Creative thinking elements are purposely infused into regular Physics curricula for fostering creativity of students. However, in the present Hong Kong contexts, constraints of time and teachers' background do not support direct instructions of thinking in normal lessons. Enhancing the understanding of the content is still a core concern of most teachers in Hong Kong.

In the previous section, a number of western studies that discussed how to foster creativity in science learning are reviewed. However, most of the instructional designs suggested are quite sophisticated, and they are greatly different those being used by teachers in Hong Kong. The present study would demonstrate how a set of simple creative learning activities can be developed for students in Hong Kong and those in other places with similar cultural contexts. This set of activities would address to the described constraints and can be infused into normal Physics classroom teaching in senior secondary school levels. On the whole, the design of this set of learning activities is based on the creativity theories and science instructional designs found in western literature. Therefore, another aim of this study is to develop ways to adapt the western creativity-enhancing methods into Chinese classrooms.

Method

This study aims at developing a set of learning activities that foster student creativity and can be infused into Physics curricula of Hong Kong. First, based on creativity literature in western countries, a set of creative learning objectives is developed. For developing and choosing suitable strategies and activities, a set of rationales that suit Hong Kong context is then suggested. Based on these rationales and learning objectives, a set of learning strategies with some exemplar activities in Physics content are developed.

After the exemplars of activities are developed, they are tried-out in two secondary classes in Hong Kong, and are introduced to 120 senior Physics teachers in Hong Kong. The feedbacks of both the secondary students and teachers are collected and analyzed to evaluate the suitability and usefulness of this set of activities.

Learning Objectives

Based on the books of Cropley (2001) and Starko (2001), and other literature reviewed in previous section, the following learning objectives are proposed for fostering creativity in Physics learning. They involve both cognitive and affective learning objectives. The first cognitive objective is nurturing the divergent thinking abilities of students, including fluency (able to generate many idea), flexibility (able to generate many different types of ideas, or ideas from many different perspectives), novelty (able to generate unusual and novel ideas), and elaboration (able to add details to improve ideas). Besides divergent thinking abilities, the instructional designs developed by this study also aim at fostering students' sensitivity (being observant, intuitive, quick and capable in discovering changes, differences and problems), imagination (able to think into the future, impossible, and unknown), and synthesis (able to integrate divergent and convergent thinking, and basic knowledge and skills to produce creative products).

In affective aspects, the learning activities aim at cultivating students' motives in creative thinking, including their interest, confidence and value in creative thinking. Other positive attitudes favoring creativity development, including an appreciation and aspiration of creativity, being curious and imaginative, favoring challenges, willing to take sensible risks, are also targeted at in this study.

Besides these basic cognitive and affective attributes, the instructional designs developed by this study also aim at equipping students with some special thinking strategies, like brainstorming, free association, mind-map, forced association, metaphoric thinking, and creative problem-solving. To enhance all-round development, this study develops activities that foster creativity in multiple intelligence domains, including the spatial, bodily-kinesthetic, linguistic and other domains.

The above mentioned are mainly learning objectives of general creativity education. Some learning objectives are specifically designed for enhancing creativity in science domain. Unlike some program for gifted youth, this study does not aim at training students to produce novel and important piece of work in Physics. Instead, it targets at cultivating creative attitudes towards Physics, including creating an image that Physics is a creative endeavor; Physics is everywhere in our daily-life and it has infinite possibilities. Since Physics is a subject that emphasizes scientific investigation, this study also includes fostering creativity in various science process skills as its learning objectives. Students are trained to be more creative in questioning, generating hypotheses, designing experiments, and other necessary skills in open-inquiry process.

Rationales for designing and selecting the activities

Besides fulfilling the above learning objectives, the creative learning activities suggested by this study need to suit the local context. A set of rationales for designing the creative Physics activities is suggested below.

First of all, to allow room for creative thinking, the tasks involved must be highly open-ended, with large solution spans. They should be of medium level of difficulties to provide acceptable challenges, and able to encourage student to take sensible risks.

If possible, playful, affective, personal and daily-life elements should be induced into the activities to make them interesting and appealing to students, and, at the same time, elicit motivation to create. And, of course, teachers need to ensure that students have equipped with sufficient Physics knowledge to engage in the tasks.

Besides fulfilling the requirements of creative learning, the design of the activities also need to cope with the various constraints in the existing Physics learning contexts of Hong Kong. In the beginning stage, we better avoid inducing great or comprehensive changes to the existing curriculum designs or to the "normal teaching" (in teachers' wording). To achieve this, the creative activities should be integrated into the knowledge content of the existing Physics curricula. Participating these activities would not only enhance creative thinking but also knowledge understanding. At the same time, the activities should be simple and flexible. They better can be finished within 10 to 20 minutes in classroom. If not, then the activities better can be completed by students independently with only a simple worksheet or guideline at home. Both the production and sharing of student work are convenient and quick.

Due to the lack of resources and the low student learning skills, several criteria become important in designing the activities. Advanced practical skills, rare resources and large physical place should not be required in doing the activities. Emphasis should be put on toying of ideas, instead of routine hands-on work. Even if there is practical work, it is better to be very simple, using mostly everyday resources. Besides being careful in designing practical work, teachers should pay special attention to the demand in students' communication and cooperation skills. The methods of communication should be easy and flexible, and avoid creating additional working pressure to students. As far as possible, both the questions and the possible answers are short and easy to understand or express. The activities have the flexibility of allowing students to express their ideas either in written, verbal, or diagrammatic ways. Wrong words or grammars are allowed. Quality of presentation is not counted in assessing student performance. Besides, complex cooperation skills should also be avoided. Though Foster (1985) proposed that cooperative group setting can improve creative thinking in science learning, however, complicated cooperative group work may increase the difficulties of beginners. Preferably, the activities have flexibility in using both group and individual work. That means, either mode of learning can lead to satisfactory performance, and teachers can choose the most suitable mode for their students.

Finally, for wide dissemination of the creative learning ideas in Hong Kong, the activities suggested need to be easily understood, designed and conducted by normal teachers with no special learning background in creativity. For example, teachers may not know what is meant by SCAMPER, though it is a common strategy in creativity field. Activities adopting this strategy are not suitable at this preliminary stage.

Methods used to generate activity designs

Adopting the rationales described, this study develops the learning activities in the following ways. First, it starts with the common teaching activities, like questioning, giving examples, explaining phenomenon, and doing experiments. In the past, teachers would ask questions and give explanations, but now students are asked to do these tasks. In short, the first method is simply reversing the role of teachers and students -- changing teacher activities in conventional classroom to student activities.

Second, it induces more freedom of exploration and self-directed elements into the inquiry, discovery and problem-solving process. In the past, teachers gave detailed guidelines and procedures and students do the "cook-book" experiments, but now teachers ask students to design both the purposes and methods of the experiments. Students are given some ill-structured and daily-life problems to start the inquiry or problem-solving work. The tasks have room for diversified answers, and yet, they are simple and can be completed quickly in classroom (at least for the thinking part of it) or independently at home. To achieve this, the original creative problem solving and open inquiry model are simplified, and simple procedures are put down in worksheet form.

Third, this study purposely induces divergent thinking training in nearly all tasks suggested. In the past, teachers were contended with one or a few correct answers in student work, but now teachers encourage the expression of fluency, flexibility, novelty and elaboration in student work. For simple tasks, a large number of answers are requested to stimulate fluency. The tasks would request either 10 or more answers in individual work, and 20 or more answers in group work. Sometimes, they simply state that "give as many answers as possible". For difficult or complicated tasks, only one single but novel and imaginative answer is requested. In fact, the number of answers requested depends on the difficulties of the questions. For encouraging flexibility and elaboration, students are explicitly asked to give more different categories of answer, to change directions, or to give more details and elaborations of the answers. In short, common tasks can also foster divergent thinking abilities, provided additional instructions on answering are given.

In strict sense, the above three methods are not creating totally new instructional designs, but modifying existing ones to give more room for creative thinking. However, in this study, some new activities need to be developed to achieve the specific learning objectives described in previous section. For example, to encourage student flexibility, some unusual way of questioning, that forced students to deviate from the norm, are suggested. The instructional designs include questioning in reverse manner, asking students to redesign some standard experiments, rewrite standard theories or ideas, adding and eliminating some well-accepted things. To encourage imagination, students are asked to make predictions and answer some "suppose" or "what if" questions. To encourage sensitivity, teaches ask students to use their five senses and their intuition to make guess, to discover phenomena, problems, uncertainties, discrepancies and changes that are difficult to be discovered. To encourage creative expression in multiple intelligence domains, students are asked to express their physics understandings in creative writing, drama, role-play, models, drawings, and the other ways. To equip with some idea-generating heuristics, activities like creating analogies, comparing metaphors, and making invention by forced association are proposed.

After reading the above paragraphs or the simple exemplars suggested in next section, one may think that creative Physics activities are rather easy to design. However, this may not always be true. Most of the tasks in the traditional science textbooks have only one solution. To elicit creative thinking, tasks involved need to have many possible solutions. It is sometimes difficult to modify them to include large solution span. Even though the creative tasks need to be so open-ended, and yet they need to be specific and concrete so that students feel easy to start with and quick to finish. Moreover, the best activities are those that can give a surprise to students. These activities involve questions that students have never thought of, but when they start to think, most students can find a lot of amazing answers that are unexpected to them. Besides these demanding and nearly contradictory criteria, the tasks need to fulfill the many other criteria mentioned in last section. How can this be achieved? The last method suggested by this study for designing activities is "brainstorming". For each kind of instructional design, a large number of possible tasks are brainstormed, and only tasks that fulfilled most of the criteria are finally chosen.

Learning activities developed

Following the methods described in previous sections, a number of creative learning activities are developed for everyday Physics lessons. They are listed in Table 1, according to their major learning objectives designed to achieve. Besides the major objective indicated in the table, these activities may also enhance other cognitive and affective objectives.

Table 1. Suggested list of learning activities for fostering creativity in Physics

Major learning objectives	Learning activities
1. Curiosity & free association	Free questioning, mind-map,
2. Fluency	Brainstorm multiple examples, multiple experimental methods, and multiple research questions
3. Flexibility	Re-design standard items, reverse thinking
4. Sensitivity	Make guess with direct senses or intuition, problem-finding, open discovery
5. Imagination	Make predictions, answer "suppose/ what if" questions
6. Metaphoric thinking	Create analogies or metaphors, compare the similarities and differences of two loosely-related concepts
7. Creativity in multiple intelligences	Construct models, draw pictures or diagrams, creative writing, creative dramatics (e.g. role-play)
8. Special idea-generating strategies	e.g. Invention using "forced association" or "adding and eliminating"method
9. Advanced synthetic thinking	Open inquiry, creative problem-solving, system design

With reference to the present Physics syllabuses of Hong Kong, exemplars of creative learning activities are developed. Some of them are listed in Table 2.

Table 2. Exemplars of Physics learning activities for fostering creativity

Learning activities	**Exemplars in Physics**
Free questioning	Q1. What you wish to know around this toy trick? Try to ask as many questions as you can.(at least 50!)
Mind-map	Q2. What do you think of when I say "mechanics". Draw a mind-map around it.
Multiple examples	Q3. Write down as many examples of friction as you can. (can be a hundred !)
Multiple research questions	Q4. If you can go to a new planet, what scientific questions do you want to research?
Multiple experimental methods	Q5. Develop, at least, 10 methods to illustrate the principle of lever with everyday objects.
Re-designing standard / well-known items	Q6. Find an alternative method to illustrate the theory demonstrated by Galileo's thought experiment.
Reverse thinking	Q7. How to increase energy loss in a machine? Invent a machine(e.g. pulley system) that you think is the "worst".
Making guess (using direct senses or intuition)	Q9. If a ball falls freely from a 10 storey-high building, how long it would take to reach the ground. Explain why you make such a guess.
Problem-finding	Q8. After connecting to a resistor, the pointer of the multi-meter does not move. Suggest 10 possible reasons.
Open discovery	Q17. Try to discover as many physical phenomena as you can in your home toilet.
Making prediction	Q10. What advancements do you think we would have in telecommunication 100 years later?
Suppose/ what if	Q11. Suppose there is no gravity, describe how the world would be like? Give 10 possible happenings
Designing models	Q12. Suggest a new diagrammatic representation for the concept "field"
Creative writing	Q13. Write a passage starting with "I am an air particle in a sound wave..."

Creative drama	Q14. Role-play the longitudinal and transverse wave
Metaphoric comparison	Q15. Give 5 similarities and 5 differences between force and love
Creating analogies	Q16. Suggest an analogy for internal temperature, heat and temperature. Explain your answer.
Invention -- brainstorming	Q17. Please design 3 electric/ electronic inventions so as to make your toilet more comfortable, convenient or useful.
Invention-- adding & eliminating	Q18. Suggest one electronic/electric devices in laboratory which you wish to add or eliminate. Give your reasons.
Invention - forced association	Q19. Combining shoes with magnet/ motor/ thermometer/..., suggest 10 possible inventions.
Open inquiry	Q 20. There are two kinds of light bulbs. Design 3 different methods to test which one is "better".
Creative problem - solving	Q21. Many people died in fire. How to help them? Adopt a simplified CPS model to solve this problem.
System design	Q22. Design a system for human beings to live on the moon. Describe its elements and their interactions in the system.

Implementation of the creative activities in classroom

Some suggested activities were tried-out in two senior science classes in Hong Kong. These activities were packed together and conducted to the students in several lessons by the researcher. Form 6 classes in two secondary schools were chosen. The schools chosen are of fairly good academic level with not much problems in discipline and writing. In the try-out, students were instructed to brainstorm as many answers as they can, and encouraged to express their ideas in simplest and quickest ways. Instructions like "There is no right and wrong answers, any reasonable answers are accepted. It does not matter to have wrong words or Chinese mixed with English in your answers." were given. Conductor of the activities had tried to promote a game-like, encouraging but challenging atmosphere by saying something like "today, we play something like this..."; "we have a little competition to see who got the most answers..."; "this question should have more than fifty answers...", "Good, someone already get ten, how about you?" After trying each question, there was a simple sharing and discussion either in small groups or with the whole class.

After finishing all the exercises, students were asked to give some written feedback on the activities. Questions included "what are your feeling towards these exercises?", "how are they different from exercises in normal Physics lessons?", and "what you have learnt in doing these exercises?". The feedbacks of the students were analyzed and summarized.

Introduction to Physics teachers

The complete set of creative activities developed was introduced to 120 senior Physics teachers in three teacher training workshops. This teacher sample comes from 120 different secondary schools, and can be considered as a good representation of Physics teachers in Hong Kong.

Each teacher participated a three-hour workshop, in which, the teachers first tried these activities themselves. The workshop also included a brief discussion on how these activities are designed and the sharing of student answers and feedback in doing these activities. After gaining substantial understanding of the activities, the teachers were asked to respond to a questionnaire that evaluates their opinions on the suggested activities. The questionnaire includes 38 items in a 7-point Likert scale. For example, teachers were asked to indicate whether they strongly agree, agree, slightly agree, have no idea, slightly disagree, disagree or strongly disagree with statement like "This kind of activities is suitable to students in my classes". In the same questionnaire, these teachers were also asked to indicate whether they would implement these activities in their future teaching, and respond to an open-ended question "after this workshop, what changes you expect you would have in your Physics teaching?".

Results

Student evaluation

On the whole, most students in this study could respond to most of the tasks given in 10 to 20 minutes. Some of them gave plenty of answers, while others' responses were slower. Some of their answers were quite interesting or creative. For the more comprehensive tasks like Question 20, 21 and 22, most students can generate answers with some relevant ideas, thought they not so complete. Among all the questions, students showed greatest difficulties in answering Question 6, 12, 16 an 18. Sample of students' answers are shown in appendix of this paper. The performance of the students indicated that the activities suggested are, on the average, suitable to this group of students.

The written feedbacks of the students on these activities can be classified into four groups. They are (1) direct feelings towards the activities, (2) perceived learning outcomes in Physics learning, (3) perceived learning outcomes in creativity development, and (4) their puzzle and worries in the activities.

Concerning direct feelings towards these activities, nearly all of the students feel that the activities are quite different from that in their normal classroom learning, giving them an innovative learning experience. They wrote:

" ... use a new approach to treat something which we already get used to, ... quite novel"

"(I) seldom think about these questions in normal days... (what learnt in this lesson) is greatly different from that in normal lesson."

Most of the students expressed that the activities are interesting and full of fun. They used to describe them as games and play. Their feedback are :

"Amazing ! (Before this activity) I do not know that Physics can be played in this way"

"Very happy! Normal days (I) seldom think crazy things. Now, (I) have the opportunity to imagine these unusual and amazing things. An exciting game!"

"Recently, workload and pressure is great. Today, it is valuable to have time to a have a little rest, to play and relax."

On the other hand, some students had mixed feelings. They felt that the activities are quite difficult, need to think very hard and yet still like doing them.

"I found the invention of Physics is quite difficult but at the same time quite funny?"

"Very playful, but the process of imagination is very difficult, especially in breaking away from my original knowledge in Physics to create something new"

Concerning learning outcomes in Physics domain, more than half of them expressed that, through participating in these activities, they discovered that Physics is more related to daily-life than they think before. They said,

"let me know Physics is not just study and calculation, but it's related to life"

"...I can feel that physics is closely related to our daily lives. I can actually invent some things that may be really used"

"the activities can make me understand how many things science involves in"

Another perceived outcome was that interest in Physics was enhanced. They mentioned,

"...this is a quite interesting game on Physics. I think exploration on Physics is very funny"

"more effectively linking Physics and daily-life, make me feel that Physics is more playful than I expected"

The activities made students think more deeply about Physics. Related responses are:

"this stimulates me think more deeply in Physics and in things happening in daily lives"

"...I like especially the part of comparing force and love. It really provides a chance for me to think deep and think of the things that I've never think of."

The activities strengthen an image that Physics is creative. Students said,

"...I understand now that Physics can also be created and used in daily-life"

"...Physics provides room for imagination."

"...science is actually developed from creativity"

Some students realize that their Physics knowledge is not enough. They gave these responses:

"(I) recognize that my Physics level is not that good after doing these exercises."

"I feel my Physics knowledge is too limited today"

Concerning learning outcomes in creativity development, some students felt that these activities made them think more, think wider and enhanced their creative thinking.

"I've learnt to think more in different aspects"

"... should use imagination more, more flexible thinking"

"... don't restrict by other things...."

For other students, their confidence and value in creativity were enhanced. They said,

"... I can think of something that normally I cannot imagine, ? Understand that creativity is very important"

"I discover that creativity of a person can be enhanced in anytime like this"

Whereas other students were aware that they did not have enough creativity and need to develop their creativity more. Their feedbacks are:

"I discover that I do not have creativity, all I know are only those from lesson"

"I realize that I really lack creative thinking skills. Many simple things I fail to realize"

"My creativity seems not so enough. (I need to) learn harder on creative thinking, ...

A few students did express some worries and puzzles on the activities, including inadequate time for thinking and sharing, and not knowing what was learnt. Their responses are:

"...It will be better for us to speak more and share our ideas. Also, we have not enough time for

thinking"
"It is fun, but at the end, I am sleepy,…. I do not understand how this lesson can help to increase our creativity"
"I do not know what I have learnt… It seems just play games."
"...you disturb our normal lesson, I cannot see any meaning in it..."

In conclusion, the activities developed were novel and interesting to the students. Students felt that they are useful to their Physics learning and creativity development. But some students had some hesitations and concerns in them.

Teacher evaluation

The results of teacher evaluation are shown in Table 3, 4, 5 and 6. Nearly all (more than 90% of) teachers agreed (including slightly agree and strongly agree) that this set of activities can enhance creativity, divergent thinking abilities and imagination of students. For affective learning outcomes, nearly all teachers agreed that they can cultivate students' interest, confidence and value in creative thinking, and also their curiosity. For Physics learning, nearly all teachers agreed that they can enhance students' learning interest in Physics and a daily-life image of Physics. Some teachers also believed that these activities can improve the conceptual understanding and memory of students in Physics, but less in number. (see Table 3)

Table 3. Teachers' opinion on the learning outcomes of the activities

Learning objectives	% Agree	% Disagree
Can enhance		
creativity (general)	100	0%
creativity in Physics	97	3%
divergent thinking, like fluency, flexibility, novelty and elaboration	100	0
imagination	97	3
sensitivity	86	0
interest, confidence and value in creative thinking	94	0
curiosity	91	3

challenge-taking and risk-taking attitudes	86	3
interest in Physics learning	94	3
an image that Physics is highly related with daily-life	91	3
an image that Physics is a creative domain	89	3
memory of Physics knowledge	72	11
aspiration to become a scientist in Physics	66	20
conceptual understanding in Physics	66	17

The result in Table 4 revealed that, around 70% of teachers agreed that this set of Physics activities can be infused into the Physics curricula. Teachers thought that the activities are more suitable for the new curricular reform than for the existing traditional curriculum. They are more suitable for junior levels than for senior levels, and more suitable for project work and extracurricular activities than for classroom learning. In fact, nearly all teachers (more than 90 %) agreed that they can be infused into Form 1 to 3 science syllabus and Physics project work. Only about half the teachers agreed that these activities can be used in the assessment of Physics learning.

Table 4. Teachers' opinion on the suitability of the activities to Physics curricula

Physics curricula	% Agree	% Disagree
Can be infused into		
the coming new Physics syllabuses	77	6
the existing Physics syllabuses	69	14
the Physics topics in Form 1 to 3 Science syllabus	94	0
Form 4 & 5 Physics syllabus	77	9
Form 6 & 7 Physics syllabus	66	17
Physics project work	94	6
Physics extra-curricular activities	83	9
Physics classroom lessons	89	6
Physics assessment	51	20

Note. "% agree" include % of teachers who strongly agree, agree and slightly agree the statement. "% disagree" include % of teachers who strongly disagree, disagree and slightly disagree the statement. The % of teachers who have no ideas on the statement is not reported.

The result in Table 5 and 6 showed that around 80% of teachers agreed that this set of activities is suitable for their own students and other students in Hong Kong, and doing them is not out of students' capacity. However, in evaluating the suitability of the activities to teachers, teachers showed less confidence in it. 66% of teachers agreed that conducting this kind of activities is not too difficult to them. Their confidence in designing and assessing these activities were even lower. Less than half of the teachers agreed that most Physics teachers in Hong Kong can design, conduct and assess this kind of activities. Teachers were not sure other Hong Kong teachers have the abilities to infuse these activities into their Physics teaching. Table 6 showed teachers' opinion on the some suggested problems of the activities. A high percentage of teachers agreed that the activities would cause serious troubles to their classroom management (63%) and greatly delay their teaching schedule (80%).

Table 5. Teachers' opinion on the suitability of the activities to teachers and students

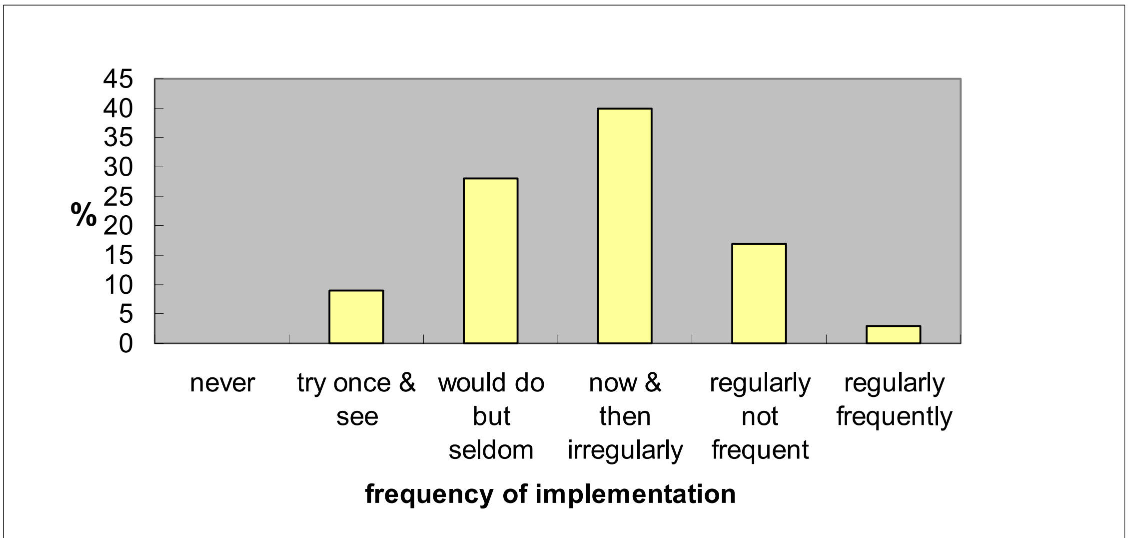
Items	**% Agree**	**% Disagree**
This kind of activities is suitable for students in my classes	83	12
This kind of activities is suitable for most secondary students in HK	74	11
To me, designing this kind of activities is not too difficult	49	37
To me, conducting this kind of activities is not too difficult	66	29
To me, assessing learning in this kind of activities is not too difficult	43	46
Most Physics teachers in HK can design this kind of activities	46	29
Most Physics teachers in HK can conduct this kind of activities	49	23
Most Physics teachers in HK can assess learning in this kind of activities	40	34.3

Table 6. Teachers' opinion on the negative impact of the suggested activities

Items	% Agree	% Disagree
Doing these activities would greatly delay my teaching schedule	80	12
Doing these activities would cause serious troubles to my classroom management	63	23
Doing these activities would do great harm on students' examination results	26	49
Teaching these activities are out of my own capacity	20	66
Doing these activities are not learning Physics	6	81
Doing these activities are wasting students' time	0	74.3
Doing these activities are out of my students' capacity	3	80

For expected frequency of implementation, the result in Figure 1 indicated that about 40% of teachers confessed that in future they will now and then, but not frequently, implement this kind of activities in their teaching. About 28% will seldom teach them and 20% will infuse these activities into their normal teaching regularly. Very few of them refuse or show reluctance in trying them with their students.

Figure 1. Teachers' expectation on frequency of implementing the suggested activities



In the open-ended question that asked teachers what changes they expected they would have, teachers' feedback can be classified into three categories – (1) would try to develop students' creativity by infusing some of these creative elements into their teaching, (2) would implement these activities in schools for achieving other non-creativity-related teaching objectives, and (3) highlight difficulties and obstacles in implementing these creative activities.

Consistent with the result in Figure 1, many teachers expressed that they would try to infuse the creative learning activities into their teaching. They wrote,

> *"ask students more creative questions"*
>
> *"a new approach in lesson that is worth to be implemented"*
>
> *"plan more activities that help develop students' creativity... reconsider what I have been teaching in this area"*

Rather unexpectedly, instead of teaching for creativity, many teachers suggested that they would use these activities to achieve other teaching objectives, including inducing more variations in their teaching, enhancing learning interests of students, doing revision, developing cross-curricular learning, assessing knowledge acquisition. They wrote,

> *"(If I) have time, I would play some of these activities with students, making use of creativity (activities to) widen students interest in Physics. It does not matter using them as revision activities."*
>
> *"Use more alternatives to teach students physics"*
>
> *"not so boring while learning physics"*
>
> *"better to develop cross-curricular activities, such as Chinese(writing) and physics"*
>
> *"Can use some of the more interesting methods to assess students' Physics knowledge"*

Also unexpectedly, instead of answering what changes they expected themselves to have in the questionnaire, some of the teachers highlighted the limitations they have in implementing these activities, including time, syllabus and etc. This result echoes with that in the reported teacher survey.

> *"It is difficult to change for the high form students. Limited teaching time is one of the difficulties we have to face"*
>
> *"On the launching of new CE Physics syllabus, there will be more time for me to try different teaching strategies..."*

In short, on the whole, teachers agreed that the activities suggested are suitable for fostering creativity of students in Hong Kong, but they still have a lot worries, including the concerns on the abilities of teachers in designing, conducting and assessing the activities, and the concerns on the classroom discipline, teaching time, syllabus, and etc.

Discussion

Summary of results

Teachers' and students' evaluation results revealed that, on the whole, the suggested activities can fulfill most of the objectives they are designated to achieve, and they are suitable for fostering student creativity in Hong Kong Physics learning context. This result also gave indirect support to the methods adopted by this study for developing these activities.

In the student evaluation, consistent with the nature of most creative activities, most students felt that these Physics creative activities are interesting, playful and quite different from normal learning activities. Some students agreed that these activities make them think more, and think wider, and enhance their creativity, whereas other students aware that their creativity is not enough, and need to be put effort on this area. Besides learning outcomes in creativity domain, these activities also have impact on students' perception and attitudes in Physics learning. They discovered that Physics is more interesting, and more related to daily-life and creativity than they think before. To some students, these activities made them think more deeply in Physics and realized that their Physics knowledge is not enough. In short, the creative thinking activities in Physics are not merely useful in fostering creativity of students, but also for promoting "better" Physics learning.

Nearly all the results in the teacher evaluation echoed with that in the student evaluation. In the teacher evaluation, teachers agreed that the suggested activities can enhance both the creative thinking abilities and creative attitudes of students, and they also contribute to knowledge acquisition and conceptual understanding in Physics. In line with student opinions, teachers felt that implementing these activities not only for fostering creativity, but also for other teaching purposes, for example, creating variations in teaching, enhancing learning interests of students, doing revision, cross-curricular learning, and assessing knowledge acquisition. Based on the results in both teacher and student evaluations, this study concludes that the set of creative learning activities developed are useful to Physics education in Hong Kong.

Concerning the suitability of the activities to Hong Kong context, the teachers agreed that the activities are suitable for students of Hong Kong and can be infused into Physics curricula of Hong Kong. However, they preferred to implement them in lower forms and outside classroom learning. Though most teachers did not feel that doing these activities are out of their capacity, they were not sure whether Physics teachers of Hong Kong have the ability to design, conduct and assess these activities. In evaluating the negative impact of these activities, teachers felt that these activities would cause troubles to classroom discipline and teaching schedule. Even though they had these worries, most of them were still willing to implement these activities, at least now and then, in their teaching. On the whole, teachers' attitudes on the proposed activities were positive but with hesitation. This study concludes that the suggested activities are suitable to Physics learning in the existing Hong Kong context. However, to make them more successful, improvements in activity design, and more support to teachers and students are necessary.

Suggestions

First, in activity design, this study has proposed twenty-two different categories of creative thinking activities in Physics. Most of them include multiple learning objectives, both cognitive and affective ones. Exemplars in Physics for each category of activities were developed. Some of the activities or exemplars are well designed while some others may not, and need improvement. For example, the questions on comparing the similarities and differences between "force and love" came up with a lot of interesting and meaning answers (see Appendix), while the questions "suggest a new diagrammatic representation for the concept "field"", "find an alternative method to illustrate the theory demonstrated by Galileo’s thought experiment", and "suggest one electronic/ electric devices in laboratory which you wish to add or eliminate" seem to be difficult and have very limited responses. It seems that the tasks that require students to discard some well-accepted ideas to produce their own novel one, is much more difficult then producing many answers to simple questions. This implies that tasks for fluency training is easier and should be done before doing tasks that specifically target at stimulating flexibility. In fact, a more preferable method for enhancing flexibility of beginners is to instruct them to change approaches and give more categories of answers in doing simple tasks.

No matter what are the outcomes of the exemplar questions, teachers and educators need to be aware that individual tasks are not so important. It is the proposed categories of activities and methods used to develop them that serve as useful reference to them. This study targets at providing a comprehensive checklist for teachers to refer to when developing creative activities. However, it has not and cannot exhaust all possible categories of activities, nor suggesting enough exemplars of Physics activities. For different knowledge content, and groups of students, teachers can adopt the methods suggested by this study to design other types of creative activities to suit their needs.

Secondly, we concern about the necessary support for students. Some students felt hard and tired to imagine creative answers, while other puzzled on what were learnt in doing this kind of activities. Students in Hong Kong are used to the rote-learning mode. They need time to adapt this new mode of learning, and continuous encouragement in doing the try-outs. Teachers need to accept mistakes and ambiguities, welcome crazy answers, and always reinforce students that the tasks have plenty of answers, and they can find them. In the conception of many students, "learning" means "learning some knowledge", therefore, they do not understand what are learnt after "playing these games". Teachers need to tell them explicitly that they are learning to be more creative, and reinforce the importance of creativity development to students. Now and then, when time is available, teachers need to do debriefing of the activities, discussing with students what they have learnt and how they learn them. After students have substantial experiences in these creative activities, explicit instructions on creative thinking strategies and meta-cognition of creative thinking should also be induced in the teaching.

Thirdly, we concern about the necessary support to teachers. The teachers' evaluation results revealed that teachers do not have confidence in designing, conducting and assessing this kind of creative activities, though they are suitable for students and the Physics curricula. Due to the "non-creative background" of the teachers, substantial teacher re-training is necessary, even though these creative activities are rather simple. The results also suggest that teachers feel more comfortable to try-out these creative activities outside classroom. However, in Hong Kong, most of the teaching time is devoted to classroom teaching, science project work are still not common in higher school levels. In short, teachers' feedback inform us that creativity education has greater chance to succeed in Hong Kong, if there are more teacher training in fostering creativity, more room and resources for informal learning, reduction in class size to release the classroom management pressure, and reduction in the knowledge content of the syllabuses to spare more time for creative learning.

Culture differences

If similar study is conducted in western countries, some of the feedbacks in this study are quite unlikely to appear. We believe that , for activities that are simple and can be completed within about 10-20 minutes, few teachers in western countries would agree with strong statements like "doing these activities would greatly delay my teaching schedule", or "doing these activities would cause serious troubles to my classroom management". There are obvious differences in conception and pace of the creativity educational reforms in Asian and western countries. However, a recent review (Cheng, 2004) revealed that Singapore, Taiwan, Hong Kong and other Asian places tend to directly import instructional methods from western world. In fact, the rapid educational reforms of these places, including Hong Kong, have already received much criticism from teachers and the public.

This study suggests that, instead of adapting the advanced instructional designs from western world, these societies should take their existing curriculum and culture as the starting point of their educational reform. They should infuse creative or other thinking elements in gradual steps into their existing curriculum, explore their own ways of fostering creativity of their students, take into consideration of the difficulties their students and teachers may have, and provide adequate support to them. This study has suggested a set of learning objective, rationales of selecting activities, strategies for generating new activities, and exemplars of activities that may serve as useful reference for educators in contexts similar that of Hong Kong. However, after gaining some experience in doing this kind of activities, it is more preferably to encourage teachers to design their own creative activities to suit their own environment. Future study on how to train teacher in self-developing creative learning activities in their own contexts are of greatest importance.

Concluding remarks

To cope with such a complex cultural and instructional design problem, of course, this simple and preliminary study suffers many limitations. To obtain more reliable and in-depth results, this study should be repeated with students of more diversify backgrounds, and implementation of the activities by more teachers and their follow-up studies are necessary. Even so, this study has several significant contributions. It develops a comprehensive set of learning objectives, strategies, and activities for fostering creativity in Physics, and shed light on creative learning of other subjects. It demonstrates systematically to teachers and educators how learning activities suitable to their own contexts can be developed. It highlights that researchers should not only look for some "model" instructional methods that have ideal learning outcomes, but also develop some simple and practical ones that can be widely-accepted and implemented. Finally, this study reminds us that culture differences should be addressed in our efforts of reforming education.

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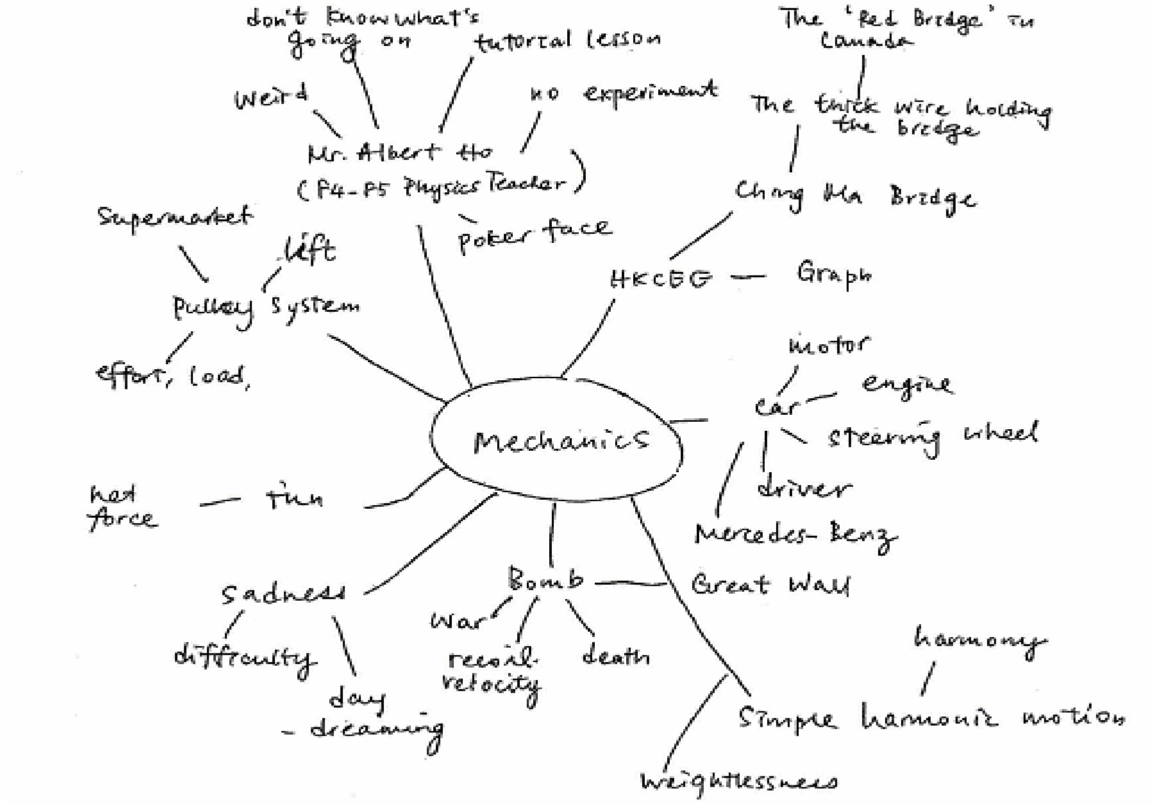
Appendix

Sample student answer of Question 2



Sample student answer of Question 13

I am an air particle in a sound wave. I
enjoy having reflection because I can
travel to another side of the world. I
hate to see interference because some
people can't hear me in a particular
point. What's the point for me to
survive without anyone to notice me?

Sample student answer of Question 15 (Similarities)

Many force / love can act on the same body at the same time

F x d = energy   love → energy

Force + love makes a body to move.

相對的   F = Action & Reaction   L: 相方面的

Something that one body acts on the other body

Cannot avoid

A balance will lead to a happy ending

when you love someone, you want to hld him/her tightly
→ larger force   mutual
F = ma   love = mutas. acceptance

There are many adversities when you love,
⇒ there is friction

Sample student answer of Question 16

有知識，努力溫書，測驗成績

because 知識要努力溫書才有，而測驗成績是個量度，正如 temperature 是 Heat 的量度

reservoir, raindrops & level of the reservoirs

because more raindrops, the water level of reservoirs increase.

Sample student answer of Question 18

I wish to eliminate the buzzer,

because its sound is too horrible and too loud.

I wish to add a device that can produce some nice music

It's use is :- to replace the buzzer to detect the input energy

It's symbol is :-

I suggest to add this because it can make the physics lab more enjoyable if there is music to listen to, so that it is less dull

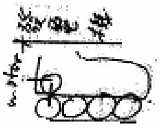
Sample student answer of Question 19

 light

 Hello!! (can speak)

 G.M tube (can detect the leakage)

 — EM wave omitted, distrub the enemy radar.

① +人力發電
roller + motor →  高速 roller

→最初幾步要自己行 跟着motor推動.

②  ultrasound. 盲人鞋

好似蝙蝠，有障礙物便「吱吱」聲

Sample student answer of Question 20