Creativity In Science Education

Tan Boon Ping
Nan Hua Secondary School

Lucille Lee Kam Wah
National Institute of Education, Nanyang Technological University

What Is Creativity?

The root of the English word "create" lies in the Latin *creare*, to make or to produce. As an English word originally meant a special ability of an individual to create something new, useful and valuable which is or will be accepted by the members of a certain culture and/ civilization, be it regional or organization. Though there is considerable period of scientific development related to creativity, today the definitions of creativity have different meanings to different people when viewed from the psychological, social and cognitive aspects. Thus, the word creativity has already lost its merely linguistic meaning and has gradually acquired a position of a new scientific term which should be defined in a new and much larger way within its own scientific frame of reference.

Researchers like Christensen (1988) refers creativity to a connecting of two or more concepts to produce a new idea or useful product while Guildford (1950) viewed creativity as a set of traits and creativity abilities are continuously distributed. Guildford also found from his study intelligence and creativity had little correlation. However Piaget (1962) perceived creativity as an imagination that will reintegrate in intelligence as children age. Creativity and intelligence will synergize and encourage each other to generate more productive activity. The nature of creative process is receptive to the progress of children through the developmental stages.

In contrast, Garrett (1989) opined that creativity be viewed differently from that of a scientist, psychologist or artist. He suggested that we should look at creativity from the scientific point of view. His concept of creativity is composed of two major components: usefulness or utility, and originality. He defined creativity as the relationship between originality, utility and creativity. To maximize creativity, utility and originality must be placed on a higher scale, so a higher originality and utility will correspond to a higher creative trait.

The lack of consensus, on what creativity is, has not been helpful for teachers who are keen to develop the creativity abilities of learners. Even though a variety of definitions has been proposed, there are common threads running through these interpretations of creativity. Firstly, creativity is seen as doing something novel, unique that is done differently from what others are doing. Secondly, creativity proceeds through an identifiable process and is verified through the uniqueness and utility of the product created.

Though creativity is difficult to define, some attempts have been made to define a creative person by making use of the adjectives of some behavioural characteristics. Even then, there are some variations in defining creativity in the western and eastern (Chinese) context. Rudowicz and Yue (2001) did a study among Mainland, Hong Kong and Taiwanese Chinese. They found that core characteristics such as originality, innovativeness, thinking and observational skills, flexibility, willingness to try, self confidence and imagination were identical in all samples. However, artistic and humorous were missing from the Chinese perception of creativity. The above characteristics of creativity perceived by the Chinese also received relatively low ratings on the desirability scale. Their results supported the notion that a part of the Chinese concept of creativity is different from that of the Western concept. Therefore, cautions should be exercised when using Western creativity tests to measure creativity among Chinese. The finding of this study is relevant to Singapore as her population contains a large population (about 70%) of Chinese. It will be helpful to see if the Singaporean version of creativity matches that of the Western's definition of creativity.

Creativity In Science Education

Though there is a need to foster creative talent in science, creativity is hardly discussed in the science education literature (Washington, 1971; Moravcsik, 1981; Garrett, 1987). Creativity and the so-called 'creative subjects' are separate areas of the curriculum commonly isolated from science and usually not thought of a proper domain of the school science laboratory (Garrett, 1987). One area in science mentioned in the literature concerning creativity is the project work (Swain, 1977). There is a shortage of literature reporting the research in creativity in the context of science education.

Fostering creativity is one of the aims for Singapore's education and it is also an integral part of the national development (MOE, 2003). 'Why is creativity an important feature in our school science curricula?' The answers are summarized by Garrett (1989):

1. It is a fundamental aspect of the *process* of science, which in turn is now being seen as a prime feature around which science curricula are being currently designed.
2. Problem solving is another key component of current courses, requires an element of creativity if it is to be practiced.
3. The sort of cognitive creativity that is required in the practice of science is not likely to be encountered in those subjects usually termed 'creativity'.
4. If creativity in all its forms is not continually exercised it will not develop. (Garrett, 1989,p.128)

The importance of creativity in science is that it contributes to the building of scientific infrastructure. Lee (2001) viewed science knowledge and process skills as the most suited for fostering creative thinking. Science instruction emphasizing creative thinking can help develop our students to become more creative citizens.

Goh, Lee, Xu, Tan and Chia, (2000) suggested that teaching science to students needs to be highly focused on getting the science concepts across without introducing any misconceptions unintentionally. Thus, creativity in science grows and blossoms in a much restricted dimension and this narrows down the space for free imagination that limits the development of creativity. This is due to the fact that the nature of science imposes precision, accuracy and reproducibility.

Tan (2001) conducted a study through a survey method, to investigate teachers' views about learning activities in relation to the promotion of creativity. Ninety-five beginning teachers and 116 experienced teachers from Singapore primary schools were involved in the study. The study has shown that activities which are student-centered with hands-on can promote better students' creativity. Thus, the responsibility of developing creativity among students rests greatly on the teachers' choice of the types of learning activities. This is supported by Goh, Lee, Xu, Tan and Chia, (2000) that certain teaching strategies in Chemistry can help to promote creativity, such as word juxtapoz, analogies, project works and science fiction. They also proposed that cultivating students' creativity through science education should have the following three stages:

1. Getting to know the fundamental science concepts,
2. Learning to see the insights of science concepts, their relevance and applications, and
3. Making use of the applications of science concepts and process skills to have a deeper coupling with languages and social arts (Goh, Lee, Xu, Tan and Chia, 2000, p.110).

As creativity is also part of the thinking process, it would not be complete if a theoretical model of creativity is not discussed. A more recent approach to identify cognitive processes and structures involved in creative thinking is the Geneplore Model by Finke, Ward and Smith (1992).

The Geneplore Model

The Geneplore model distinguishes between generative processes and explorative processes during creative cognition. It provides a useful framework within which to describe basic cognitive processes related to creativity. An explanation of this model is found in the book, "Creative Cognition: Theory, Research and Applications" by Finke, Ward and Smith (1992).

The Geneplore model is a general model of creative cognition that attempts to show that most creative endeavours result from cognitive processes. The model consists of two distinct processing components: a generative phase, followed by an exploratory phase. In the generative phase, mental representations called preinventive structures which have various properties that promote creative discovery are constructed. These properties are then exploited during an exploratory phase in which the preinventive structures are interpreted in meaningful ways. If an initial exploration results in a satisfactory resolution to a problem, the initial preinventive structure may lead directly to a creative product. If these explorations are unsuccessful, the initial preinventive structure could be abandoned and another generated that might be more promising. Or the initial structure could be modified and then the exploratory phase repeated with this modified structure.

The creative process is therefore cyclic, with the number of cycles being determined by the desired extent of the conceptual refinement or expansion. This cycling between the generative and exploratory phases normally occurs when people engage in creative thinking. For example, an individual may retrieve two images from his/her mind and combine them in the generation phase to produce a visually interesting form, and then interpret the form as suggesting a new idea or product. If the form is incomplete in some way, a modified form is then generated by retrieving yet another image and mentally combining it with the already existing one. There are also cases in which creative discoveries can occur quite rapidly, without repeated generation and exploration. It is therefore not essential to engage in repetitions of the Geneplore cycle in attempting to make creative discoveries, although this may be necessary in most instances.

Some Features of the Geneplore Model

One advantage of the Geneplore Model is that it provides an explanation of artistic creation and scientific discovery within the same general approach. It also allows for the possibility that people can be creative in different ways. Some may be more skilled at generating preinventive structures while others might be better at interpreting them.

Another advantage of this model is that it can be applied at many different stages of creative thinking. For example, it may be used at the early stages when the individual is searching for new ideas and where the preinventive structures would be relatively unconstrained or even to the later stages when he is close to solving a particular problem or completing a new design in which case the preinventive structures would be highly constrained.

The Geneplore model is viewed as the creative genius and everyday creativity as lying along a continuum and distinguished by the extent to which the creators employ creative processes. Thus, creative geniuses are probably able to generate or interpret their preinventive structures more efficiently than others or by being able to generate more useful preinventive structures in the first place.

In order to enhance creative performance, it is necessary to structure experimental tasks in such a way that creative opportunities are available. It is thus necessary to impose constraints and controls on the tasks in order to identify the specific cognitive processes that contribute to creative acts. It is equally important to devise experimental techniques in which genuine scientific and legitimate discoveries can be made. To promote creative thinking, the authors believe in the use of novel situations and unusual tasks or procedures. They also believe that in restricting the elements that can be used in generating an idea or an invention, as well as in restricting the ways in which creative cognitions can be interpreted, creative exploration and resourcefulness can be promoted. The model suggests that a strategy for creative performance is required and it involves the exploration of hypothetical possibilities and consequences which can lead to creative insights and discoveries. In addition another technique is also required to deliberately create mental blocks and explore ways to overcome them. Finally, the Geneplore model suggests assessing individual differences through a variety of personality and attitude measures in order to reveal whether certain cognitive styles might be related to particular types of creative cognitive processes.

Factors Encouraging Creativity

Finke, Ward and Smith (1992), the authors of the Geneplore Model, feel that a number of motivational factors play an important role in encouraging creativity. According to them, people are afraid of being creative for fear that their creations might be considered too wild or bizarre. As such, this is in line with the investment perspective on creativity which defines a creative individual as one who is 'buys low and sells high' because most people are risk averse, not willing to buy into ideas that may seem bizarre against unconventional wisdom. Thus, experiments on creative cognition should be designed to encourage positive attitudes towards creativity and confidence in one's potential creative performance. The individual needs to be engaged 'intimately' with a creative idea in order to make creative discoveries. They believe that one way to encourage creativity is to encourage playfulness and irrelevant thinking. This belief is supported by Lieberman (1977) that such playful traits were related to divergent thinking. Finke, Ward & Smith (1992) also suggest that the most important factor for creative thought is perhaps the joy of discovery. Furthermore, motivation is seen as another factor affecting cognition indirectly, such as in the selection of certain generative and exploratory processes.

Evaluation of Creativity

According to the Geneplore model, a creative product is evaluated in terms of its originality, practicality and sensibility, productivity and flexibility, marketability and feasibility, inclusiveness and insightfulness. The real creativity excites and inspires others to consider interesting possibilities as well. This quality of creativity goes beyond merely having consensus in the evaluation of creative work. Thus, creative work would have construct validity in that they are generally perceived as creative and inspirational by others. The last factor affecting the evaluation of creativity is the environment. Often the social and cultural environment determines what the society views as ingenious or creative. The ultimate test of creativity is whether a new idea is accepted over time even as society's values change.

Implications For Schools

What are the implications of teaching creativity in Science for the Singapore schools ? Students need to be taught about metacognition and how to be aware of their own thinking. They should know what and how to think before they can engage in creative thinking. Teachers may teach less so that their students can learn more of process skills and thinking skills to equip themselves with the cognitive processes to do creative work. Teachers provide their students an environment which is conducive for thinking to take place. Teachers teach their students certain positive habits of mind and provide them with a positive classroom climate for thinking to take place.

Although 30% of curriculum work in Singapore schools involves thinking activities, one ought to ask 'What type of thinking is actually performed by students in these activities?' and 'Are teachers teaching thinking skills to students simply for the purpose of acquiring and organizing knowledge, or helping them to generate new ideas and evaluate ideas in order to solve problems creatively ?'

The modes of assessment in schools will also have to change to focus more on the cognitive processes involving creative thinking, rather than on the end product alone. Although project work in schools at the junior college levels in Singapore does assess the process, this usually constitutes a smaller percentage of the total mark. The assessment of process skills with emphasis of creative thinking should start from the lower level, at primary school.

The implementation of School Practical Assessment (SPA) for the science practicals at the upper secondary and junior college levels is a shift from purely paper-and-pencil types of assessment to focusing on process skills. Although this is a move in the right direction in promoting thinking skills, more can still be done to encourage students to generate and explore cognitive structures that will help them to engage in creative problem solving, come up with creative discoveries in their scientific experiments, etc. They will need to be taught how to generate more useful preinventive structures and interpret them more efficiently. This should be done not only in science but across all subjects. Constraints such as ill designed problem can be inserted in assignments or projects to restrict the elements that can be used in their generation of ideas so that students are forced to engage in creative exploration.

Lastly, it would be good to assess the thinking or cognitive styles of students so as to understand their cognitive processes. In this way, teachers would be able to ascertain if certain cognitive styles are related to certain creative types of cognitive processes and to identify the "less creative" students. These students can then be taught the skills in the Geneplore model to generate more useful preinventive structures and interpret them more efficiently or the various skills used in the Thinking Programme introduced by the Ministry of Education in 1998.

References

Chritensen, J.J. (1988). Reflections on teaching creativity. *Chemical Engineering Education, 22* (4), 170-176.

Finke, R. A., Ward, T.B., & Smith, S. M. (1992). *Creative Cognition: Theory, Research and Applications.* Cambridge: The MIT Press

Garrett, R.M. (1987). Issues in science-education: Problem-solving, creativity and originality. *International Journal of Science Education, 9* (2), 125-137.

Garrett, R.M. (1989). Promoting creativity through a problem-solving science curriculum. *School Science Review, 70* (252), 127-131.

Goh, N.K, Lee, K.W.L., Xu, Y., Tan, S.N. and Chia, L.S. (2000). Teaching of creativity in science education. In Ho, S.G. (Ed), *Effective Thinking and Learning Strategies in the 21st Century.* Singapore: Singapore Chinese Teachers' Union.

Guilford, J.G. (1959). Traits of Creativity. In Anderson, H.H. (Ed.), *Creativity and its Cultivation.* London: Harper. pp. 142-161.

Lee, K.W.L. (2001). Fostering creativity in science education. *REACT 20* (2), 27-31.

Lieberman, J.N. (1977). *Playfulness: its Relationship to Imagination and Creativity.* New York: Academic Press

MOE (2003). *Desired Outcomes of Education.* Ministry of Education, Singapore. Extracted on 01 October 2004. http://www1.moe.edu.sg/desired.htm.

Moravcsik, M. (1981). Creativity in science education. *Science Education, 65*, 221-227.

Piaget, J. (1962). *Play, Dreams and Imitation in Childhood.* New York: Norton.

Rudowicz, E. and Yue, X.D. (2001). Concepts of creativity: Similarities and differences among Mainland, Hong Kong and Taiwanese Chinese. *The Journal of Creative Behaviour, 34* (3), 175-192.

Swain, J.R.L. (1977). Project work in Nuffield Physical Science. *School Science Review, 58*, 570-578.

Tan, A.G. (2001). Singaporean teachers' perception of activities useful for fostering activities. *The Journal of Creative Behaviour, 35* (2), 131-148.

Washington, N. (1971). Creativity in science education. *Science Education, 55*, 147-150.