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Understanding the Thinking of Scientists Entrepreneurs: Implications for Science Education in Malaysia

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ABSTRACT

Based on the need to develop the nation's science and technological advancement through science education, science educationists are searching for a suitable learning model that integrates innovative technological thinking. One way in conceptualizing this learning model, this study seeks to understand the thinking of scientist entrepreneurs who had produced innovative products for their business ventures. A case study approach was employed. The qualitative findings showed that the respondents integrated entrepreneurial thinking and science process skills in producing their innovative science based products. As a result, we proposed five entrepreneurial science thinking steps which can be used as a learning model in the science curriculum at both primary and secondary school levels.

Keywords: Entrepreneurial Science Thinking; Science Process Skills; Science Education.

INTRODUCTION

How does science education contribute to the economic development of a country? In today's globalized world, the wealth of a country depends on its capabilities in technological innovation. Innovation, according to Venuvinod and Sun (2002), depends on knowledge creation and occurs when knowledge is applied to tasks that are new and different. In the case of Malaysia, her 5 year Malaysian Economic Plan had consistently emphasized on the importance of science and technology education as a vehicle for economic growth, wealth creation and innovation (9th Malaysian Plan, 2006) . At the same time, knowledge for technological innovation is currently generated mostly through scientific research and development at the universities. The authors argue that this development of knowledge for innovation should begin at the school level. One of the ways to encourage this learning for innovation is through integrating entrepreneurial science thinking (EnSciT) in the curriculum. EnSciT is a blend of the science process skills and entrepreneurial orientation. This combination of two disciplines leads to the development of innovative and creative thinking process that leads to producing science

based products or ideas that are new and innovative which are presently non-existent in the markets (Buang, 2001; Halim, Buang, & Mohd. Salleh, 2003).

Thus, Malaysia has to improve the science curriculum which involves applications of design and technology thinking drawing on the scientific knowledge and understanding. For example, knowledge of alkaline and acidic qualities can be used to produce soaps that are non-acidic to the human skin. Other related international initiatives that similarly link science and technology in this way are those from Ontario (see http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec.html).

Science Education in Malaysia

As a developing nation, Malaysia strives to have a competitive edge in the world economy and global scientific and technological fields. Hence, a policy has been implemented that envisages students taking science at upper secondary school and university levels in the ratio of 60:40 (CDC, 2001). Currently, the Malaysian Curriculum Department is already working on integrating entrepreneurial element across science subjects at primary and secondary levels (CDC, 2009). Previously, the emphasis of teaching the science subjects at both the primary and secondary levels is on the mastery of the acquisition of scientific knowledge, mastery of scientific and thinking skills, inculcation of moral values concurring with the premise that man is entrusted with the responsibility of managing the world and its resources wisely. Thus, we ask "What is the best learning model that integrates the entrepreneurial orientation and science process skills?" This question leads the authors to do research on how scientist entrepreneurs integrate the two disciplines in their innovative and technology based product development.

The purpose of this study was to determine the thinking process of how these scientist entrepreneurs integrate the entrepreneurial orientation and science process skills in their innovative and technology based product development. Based on the findings, the authors suggest an EnSciT learning model to be integrated in the school science curriculum.

METHODOLOGY

This research employed a case study approach. This approach was chosen because it enables the researchers to explore in-depth the thinking processes of the respondents when they were developing their innovative and technology based product development. The respondents involved were twelve scientist-entrepreneurs who were interviewed in-depth. At the time of interview, the scientist-entrepreneurs were involved in their own businesses and their academic qualifications ranged from a PhD in Chemical Engineering to a Diploma in Chemical Agriculture. The nature of their businesses was related to their science background. The 14 semi-structured questions were developed in such a way to find out the pattern for entrepreneurial science thinking process utilized by the scientist-entrepreneurs in creating new ideas and products in their business organization. The data was analyzed using the constant comparative method which employed conceptualizing themes and patterns from the phenomena.

FINDINGS

This section is discussed based on the questions asked to the scientist entrepreneurs.

Question 1: How does your current business product/idea relate to your previous work experience and science education background?

Some of the scientist-entrepreneurs decide to sell the products that they are selling based on their discovery about the qualities of the product in the research that were doing while working. Some others discovered about the products when they were working in the related industries. They had confidence to reproduce the products in a more innovative ways because of the related science education background that they had. Some others sell the products that they had technical know how of how the products are manufactured from the science knowledge. They believe they know the products' content thoroughly.

Question 2: Why do you choose to do this kind of business? Does it have to do with your interest in science? Or it's a matter of coincidence?

Some of the scientist-entrepreneurs relate science knowledge with the products that they are selling because the results of research assure them of its qualities. They believe that the good qualities that they discovered through research should be shared with the society.

Question 3: What encourage you to relate science knowledge and your business idea/product?

i) Believe in research results of the products.
ii) Believe in scientific based quality of the products.
iii) Have confidence in doing business which relate to own background knowledge

Question 4: Do you always prefer to come up with ideas/alternative ideas that relate to science knowledge whenever you encounter business opportunity in your daily life?

i) Only prefer to take up business ideas/products that relate to science knowledge/own background whenever encounter new business opportunities.
ii) Not necessarily because believe we can always learn new things or get support from other knowledgeable people. Need to know how to manage.

Question 5: What encourage you to relate science knowledge and your business idea/product?

i) Believe in research results of the products.
ii) Believe in scientific based quality of the products.
iii) Have confidence in doing business which relate to owns background knowledge

Question 6: Do you always prefer to come up with ideas/alternative ideas that relate to science knowledge whenever you encounter business opportunity in your daily life?

i) Only prefer to take up business ideas/products that relate to science knowledge/own background whenever encounter new business opportunities.
ii) Not necessarily because believe we can always learn new things or get support from other knowledgeable people. Need to know how to manage.

Question 7: How would you go about evaluating those ideas in terms of whether it is viable for business?

i) Based on customers' problems, needs and their feedback of the products.
ii) Based on research by a specialized group in the business organization

Question 8: How much do you make use of science knowledge in your business idea/product development?

i) Use 100% of the science knowledge in their business idea/product development either through self or get help from other consultant scientists.

Question 9: How would you apply innovations in your business ideas/product?

ii) Through purposeful thinking in your daily life?
iii) Through purposeful plan of producing ideas with a group of people in your business?
iv) Through your science knowledge?

Most of the scientist entrepreneurs use all the above methods interchangeably. They purposely keep thinking of ways to improve their products so that customers will stay. They also have a special group who will continuously monitor the product development suitability with the customers' needs. Most of them purposely set up a research corner to test new ideas/products.

Question 10: What encourage you to innovate your business idea/product from time to time?

i) Based on customers' and needs feedback
ii) Own initiative to keep improving their products

Question 11: If you find a good business idea/product that has nothing to do with science principles/knowledge, would you indulge in the business? Or you are only interested with those that relate to science principles/knowledge?

i) Most will only indulge in business that relate to their science background.
ii) A few others would like to diversify their business in other areas as well even though not related to their science background.

Question 12: In coming up with science based business ideas/product, do you always think of its benefit to humankind or only business profit?

i) Most of the scientist-entrepreneurs admitted that think of business profit first then the benefit of their products to the humankind.
ii) Only a few think of the benefit of the products to the humankind first then only the business profit.

Question 13: How/What would you advice Malaysian students who are in the pure science stream to be entrepreneurs in businesses that utilizes their science knowledge after they graduated?

i) Emphasize the importance of having basic knowledge or degree in science as a tool to be entrepreneurs.
ii) Emphasize the importance of co-curriculum which develop students' surviving or independence personality/character.
iii) Emphasize the importance of working on their own working for others.
iv) Emphasize the importance of introducing entrepreneurship courses at the school level to the science students.
v) Emphasize the importance of thinking skills such as creativity and logical thinking.
vi) Emphasize the importance of self-development at the university level.
vii) Emphasize the importance of language skills whether acquisition or communicative skills.

Question 14: Do you think this (no. 11) will encourage fast technological development in our country like other countries such USA, Korea, Taiwan, Japan and Germany? Why do you think so?

i) Most agreed that must introduce the combination of knowledge in science, technology and entrepreneurship at the school level to encourage fast technological development because entrepreneurship brings science and technology to the reality of human needs in terms of adaptability and modification.
ii) Proposed that university students must have sense of self-direction for their future, sense of independency and self development in life skills other than academic achievements.
iii) Government support in terms of capital and many others at the business level

DISCUSSION

Most of the scientist entrepreneurs use their observation skills but extend it to the need of the people within business contexts. What is meant by business context is the means for them to develop the product and get the products reach the customers to solve their problems, meet their needs or create new human needs. In the process of developing new ideas or products, they used a lot of hypothesizing skills such as understanding customers' problems first and thus what they will need. Some others foresee the future development of human environment and predict their new needs. In hypothesizing future product development, they integrate entrepreneurial skills such as listing a lot alternative ideas through purposeful thinking and group discussion. They tend to test those ideas

through market research and lab research. Most of the scientist entrepreneurs use 'experimenting' approach in their research in order to find the most viable idea in terms of product quality and market viability. From the research, scientist-entrepreneurs will improve their products (innovation) or create new products which suits human needs and can be adapted easily by people.

In comparing the thinking processes shared by the above scientist entrepreneurs to the general models of problem solving process, technology or design process, science process skills and entrepreneurial thinking process; the findings showed that EnSciT processes led to the use of innovative and creative thinking before coming up with a solution or idea. The researchers also identified that the difference between technology or design process depends on when the need arises to start the process of problem solving whereas EnSciT begins with the process of problem solving through purposeful daily observations of the surroundings to find something useful. In addition, the EnSciT process ends with determining the feasibility of the end products in terms of people's usage and its commercialization. Table 1 shows the different problem-solving processes in different disciplines.

Table 1. *Comparison of Various Models of Problem Solving Processes from Different Disciplines*

General Model	**Science Process**	**Technology/ Design process**	**Entrepreneurial Thinking**	**Entrepreneurial Science Thinking (EnSciT)**
1.Understand the problem 2.Describe the problem 3.Consider alternative solution 4.Choose one solution 5.Take action 6.Evaluate the product	1.Observe a natural phenomenon 2.Describe the phenomena 3.Suggest hypothesis 4.Select one hypothesis 5.Conduct an experiment 6.Does result fit hypothesis?	1.Determine the need 2.Describe the need 3.Formulate ideas 4.Select one idea 5.Make/ Develop product 6.Test product	1. Purposely observe the environment 2. Discover the need 3. Formulate ideas 4. Select one idea 5. Make product 6. Test product 7. Adapt to the environment based on cost, marketability and usage	1. Take initiatives to observe purposely, deliberately and continuously 2. Keep thinking to find uniqueness or 'different' of the observed phenomena in the form of new ideas/system/product/ model/technology/design 3. Select a few ideas from the above that might be successful for innovation and evaluate them. 4.Purposeful enhance-ment and improve-ment of ideas (Design and redesign) 5. To create value added to the ideas/products in terms of value creation to the society/community

This conceptualization of EnSciT model can be further explained or supported by some literature reviews. For example, entrepreneurial thinking is referred to as a cognitive phenomenon for searching innovative and creative entrepreneurial ideas or opportunities (Krueger, 2003). Science process skills as defined in the Malaysian Science Curriculum are skills that enable science students to formulate questions and find out answers systematically. Those skills include observing, classifying, inferring, predicting,

communicating and hypothesizing. Based on the interview findings, there are some similar orientations between steps in the science process skills and entrepreneurial thinking. These similar orientations can be clearly explained by comparing the two different processes from two different disciplines based on the general problem solving process model as depicted in Table 1.

Table 1 also compares technology/design process with the general problem solving process model for the purpose of showing that problem solving has always been the ultimate aim of any thinking process. Thus, based on this general problem solving process model, the steps in the three different disciplines can be mapped out horizontally in terms of their functional similarities. For example, a common first step in science process skills is making an "observation." As Harlen (1996) indicated, almost any scientific activity begins with observation and it is part of identifying a problem or raising a question. In addition the Malaysian Science Curriculum considers the science process skill of "observation" as the first step in enabling students to formulate their questions. In entrepreneurial thinking, making an observation is also the first necessary step towards creating new ideas. However, the purpose of doing observation in the two disciplines have some overlap; in science it is to understand the phenomena and the other one (entrepreneurial) besides understanding the phenomena, is to look for how some features of the observed phenomena can be used as a base to create something (Forbes 1999; Krueger, 2003). In other words, both disciplines have the "observation" step but the entrepreneurial part extends it beyond just understanding the phenomena. The rest of the steps in the entrepreneurial thinking and science process skills are almost similar in functions except for the last step in EnSciT it extends to create value added to the ideas/products in terms of value creation to the society or community.

CONCLUSION

The findings found that almost all of the scientist-entrepreneurs used observation step but extended it beyond just to understand and describe the phenomena, that is, how this phenomena (i.e. a science concept) can be used as a base to create something for the people thus create a need. Since they have the elements of entrepreneurial orientations while applying the science process skills in coming up with new ideas or products, they tend to depend very much on their observations of the daily phenomena of what products people might need for more efficient living. In other words, they think of creating new human needs. In the process of developing new ideas or products, they used a lot of hypothesizing skill such as understanding peoples' characteristics first and thus what they need to make their lives better. In hypothesizing future product development, they integrate entrepreneurial skills such as listing many alternative ideas through purposeful thinking and group discussion. They tend to test those ideas through market research and laboratory research. Most of these scientist entrepreneurs used an "experimenting" approach in their research in order to find the most viable ideas in terms of the product quality and market viability. Based on the research findings, scientist-entrepreneurs will innovate their products or create new products based on their understandings of science concepts as well as acceptable and adapted easily by the society. This finding is in agreement with the previous cited literature reviews.

In conclusion, scientist-entrepreneurs have the entrepreneurial orientation or inclination added to their knowledge of science process skills. They also tend to use research as the foundation for testing, improving and creating new ideas or products in their business organization. They also proposed that science students should learn

independence living skills, creative and innovative thinking skills and language skills besides acquiring science process skills. In conclusion, science students should be taught other aspects of human development skills (in this case entrepreneurial skills) from the school level to ensure that at the university level they will continue to develop themselves. This approach might be effective in producing a lot of scientist-entrepreneurs who will then highly motivated to create a lot of new technologies for Malaysia. This results in Malaysia able to compete globally in fast technology development era. Finally, the authors suggest an EnScit learning model. This model is based on the integration of science and entrepreneurship discipline. The integration of these disciplines resulted in the first science learning model that inculcates design thinking skills based on science content knowledge with an entrepreneurial orientation. This model consists of five major steps such as:

1) Take initiatives to observe purposefully, deliberately and continuously,

2) Keep thinking to find uniqueness or 'different' of the observed phenomena in the form of new idea/system/product/ model/ technology/design,

3) Select a few ideas from the above that might be successful for innovation and evaluate them,

4) Purposeful enhancement and improvement of ideas (design and redesign), and

5) To create value added to the ideas/products in terms of value creation to the society/community.

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