Some Thoughts on Designing Multimedia Courseware as a Tool for Enhancing Process and Thinking Skills in Chemical Education

Tsoi Mun Fie Raymond, Goh Ngoh Khang and Chia Lian Sai

ABSTRACT

The importance placed on a 'process-led' curriculum in science and chemical education does suggest a need for effective teaching and learning of science process skills such as manipulative, observation and inference skills. Besides, the ability to establish the connections among the three levels of understanding, namely, macroscopic, microscopic, and symbolic is also a difficult task for students. Shortcomings such as time constraints, safety factors, the limitations of textbooks in providing minimal visual images of macroscopic or microscopic events, and limited learning experience especially in the area of thinking skills do exist. As such, this paper concentrates on the enhancement of both process and thinking skills through interactive multimedia design including visualizations, for example, computer graphics or animations; videos and graphic organizers.

INTRODUCTION

In the teaching and learning of process skills in science and chemical education, the common practice employed is mainly to demonstrate known concepts and provide hands-on laboratory based activities, rather than to promote the mastery of process skills such as manipulative, observation and inference. Numerous factors, like time constraints, operating costs, safety aspects, limitations of science textbooks in providing visual images of macroscopic or microscopic events that are static in nature, as well as limited learning experience, especially in the domains of thinking skills, also aggravate this situation. Since process skills like the thinking skills could be transferred to situations that require inquiry and problem solving, the acquisition of such science process skills and thinking skills would then be essential. Research studies have also found that the teaching and learning of science process skills can influence formal thinking ability as well as promote Piagetian development (Brotherton & Preece, 1996).

Therefore, the development and application of multimedia technology could be one way to address these issues and to promote not only process skills but also thinking skills. The strength of such multimedia is that it uses our human natural abilities of information processing where our eyes and ears, with our brain, transform the wide variety of data into information (Grabe & Grabe, 1996). Indeed, multimedia CD-ROMs, integrating various presentation modes such as text, images, sound, videos, graphics, and animation, could be used to supplement the learning experience, and also to allow students to be more exposed to the three levels of understanding (Johnstone, 1991; Gabel, 1993). They are (a) the macroscopic level, which deals with sensory/visible phenomena such as laboratory observations and data; (b) the microscopic level, which deals with particles such as atoms, ions and molecules; and (c) the symbolic level, which represents the matter in terms of chemical formulae and equations (Ben-Zvi & Gai, 1994).

Multimedia Design

In the instructional design of learning materials, content organization plays a pivotal role and so there has to be a congruent and complementary integration of the different presentation stimuli to put across concepts in internally consistent and coherent segments. Essential design decisions such as determining the goal of the instruction and the pedagogical approach where learners are to be engaged not only in meaningful authentic tasks, but also in active learning need to be made (Wilson & Cole, 1991; Wilson, Jonassen & Cole, 1993; Boyle, 1997; Shneiderman, 1997).

The following sections provide an account of the developmental process using instructional storyboard and how the product developed. Figure 1 illustrates the dynamic process of the organic chemical reactions at the microscopic and symbolic levels. At the microscopic level, the animation of the addition reaction involves different size, colour and shape of the atoms as well as the breaking of the chemical bonds. As such, the learners are engaged visually whereby the meaning of "addition" in this organic chemical reaction is enhanced. Subsequently, the learners could make a prediction based on the information given before viewing the animations of other similar chemical reactions. Findings have also lent support to use animations that elicit effective visual and verbal information processing (Mayer & Anderson, (1991);. Park & Gittelman, 1992).

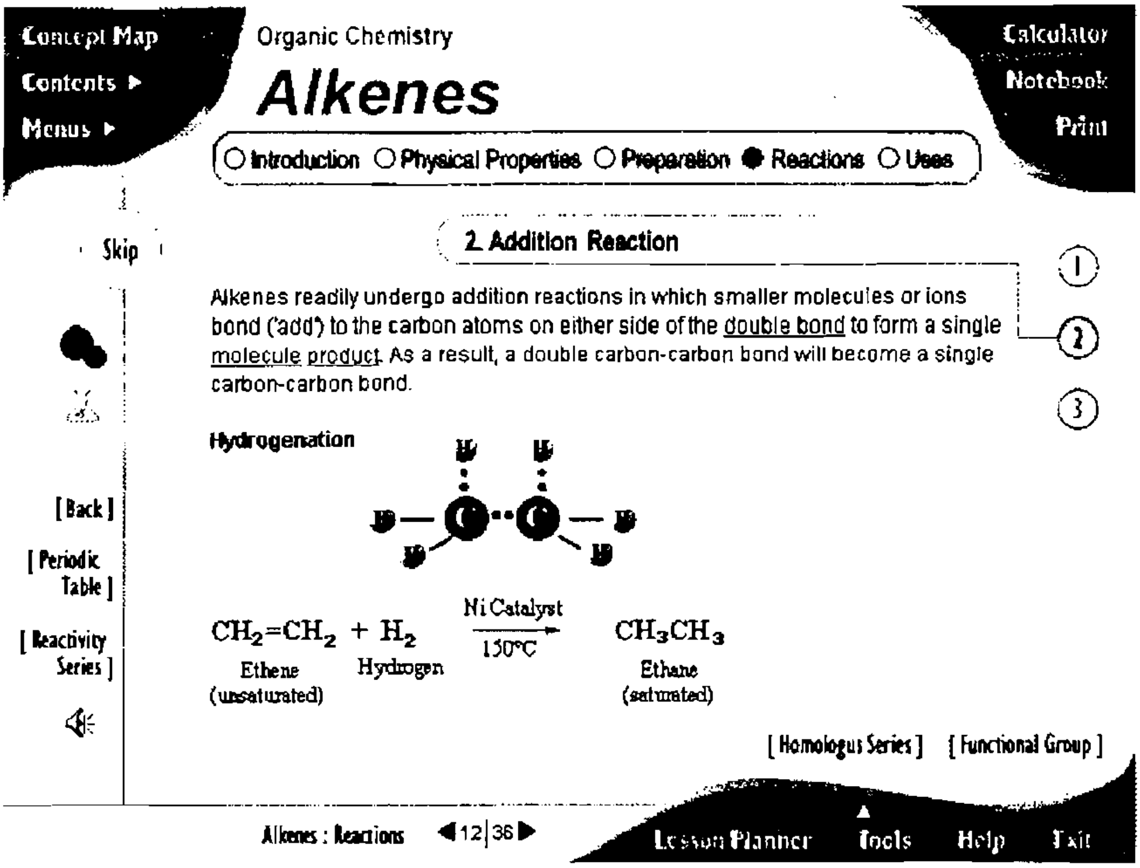

Figure 1. Organic chemistry user interface

In order to enhance the learning of chemistry, the inductive-deductive thinking skill could be incorporated explicitly in the form of a graphic organizer as shown in Figure 2. Induction is the skill of arriving at a general conclusion from specific observations after interpreting and analysing them. In this way, the learners are required to go through the thinking processes by processing the relevant information, analysing, formulating hypotheses and predicting. As such, with the aid of the graphic organizer, specific pieces of information as well as patterns or connections could be focused on leading to a statement that could explain the patterns or connections. Figure 3 is one way of representing associations in the form of a concept map. Conceptual organization of content to be learned could be improved in this way by using visual representations to show certain meaningful interrelationships (Jonassen & Wang, 1993).

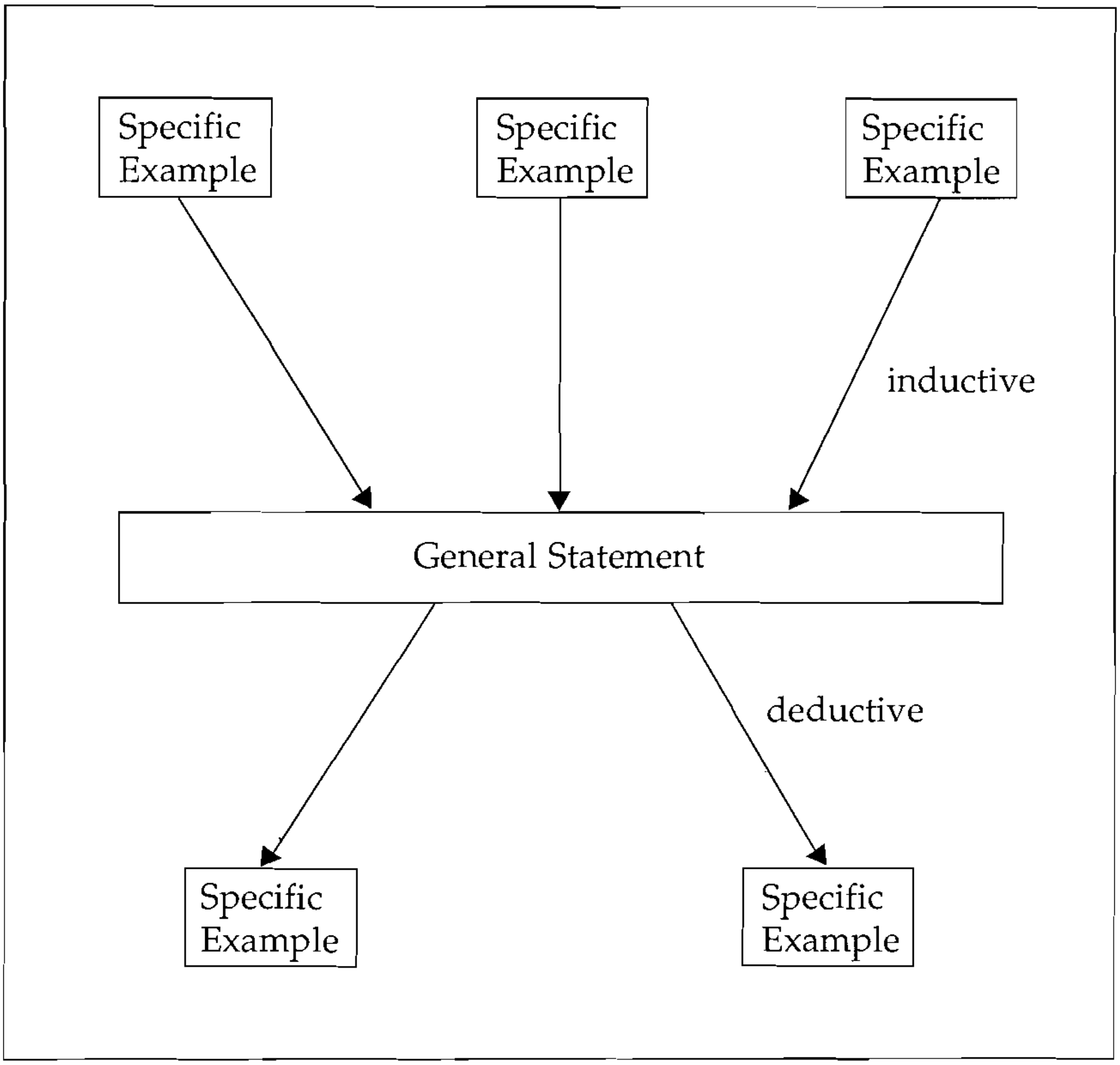

Figure 2. Graphic organizer for induction-deduction

Figure 5 illustrates the translation of the instructional storyboarding as shown in Figure 4 into the product developed. The visualizations in the form of videos cum demonstrations could serve as a powerful mechanism to elicit effective visual and verbal information processing that would help to enhance the learning process and promote the acquisition of process skills. In this context, the fundamental training for observation skills would be to allow students to practise asking questions such as 'What can I observe?', 'Did any change occur as I observed it?', 'Why do I think the change happened?'

Figure 6 is an example of a demonstration of an instructional task. Since observational learning is a critical part of the development of process skills, it is therefore important to demonstrate the task or process skill as clearly and unambiguously as possible.

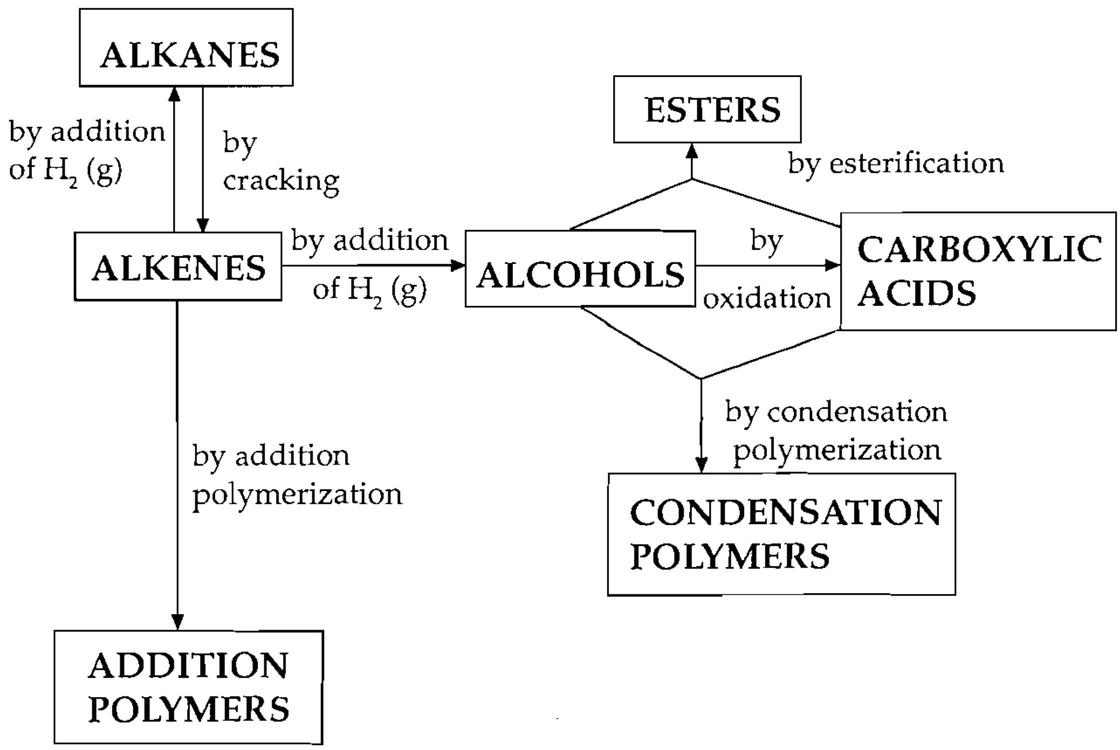

Figure 3. Concept map

Date:	**Previous:**	**Next:**	**Frame: 2020**

Project Title: CHEM 'O' LEVEL **Section:** Qualitative analysis

Screen Display/Graphic/Text: **Qualitative Analysis**
Tests for Cations
CONCEPT MAP

COLOURLESS IONS | COLOURLESS IONS

The three coloured ions are copper (II), iron (II) and iron (III).

Video on the reaction between aqueous sodium hydroxide and the coloured ions

Video on the reaction between aqueous ammonia and the coloured ions

Observe the distinct colour of the precipitate that identifies the cation.

System and General Tools ⇦ ⇨

Programming Instructions:
1. pop-up window for both videos for comparison

System Tools: Help, Tools (Search, Glossary, Internet), Main Menu, Quit, Home, Return

General Tools: Periodic Table, Concept Map, Calculator, Notepad, Lesson Planner, Print, summary

Figure 4. Instructional Storyboard

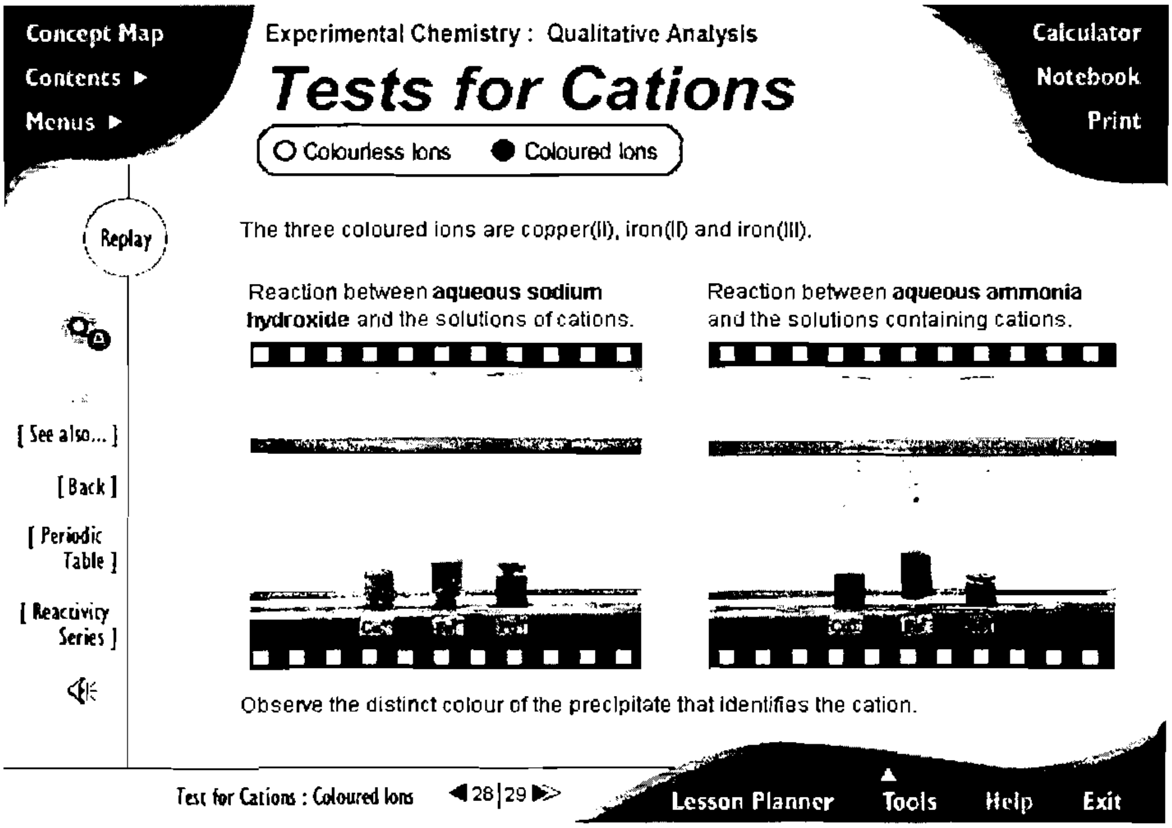

Figure 5. Experimental chemistry user interface

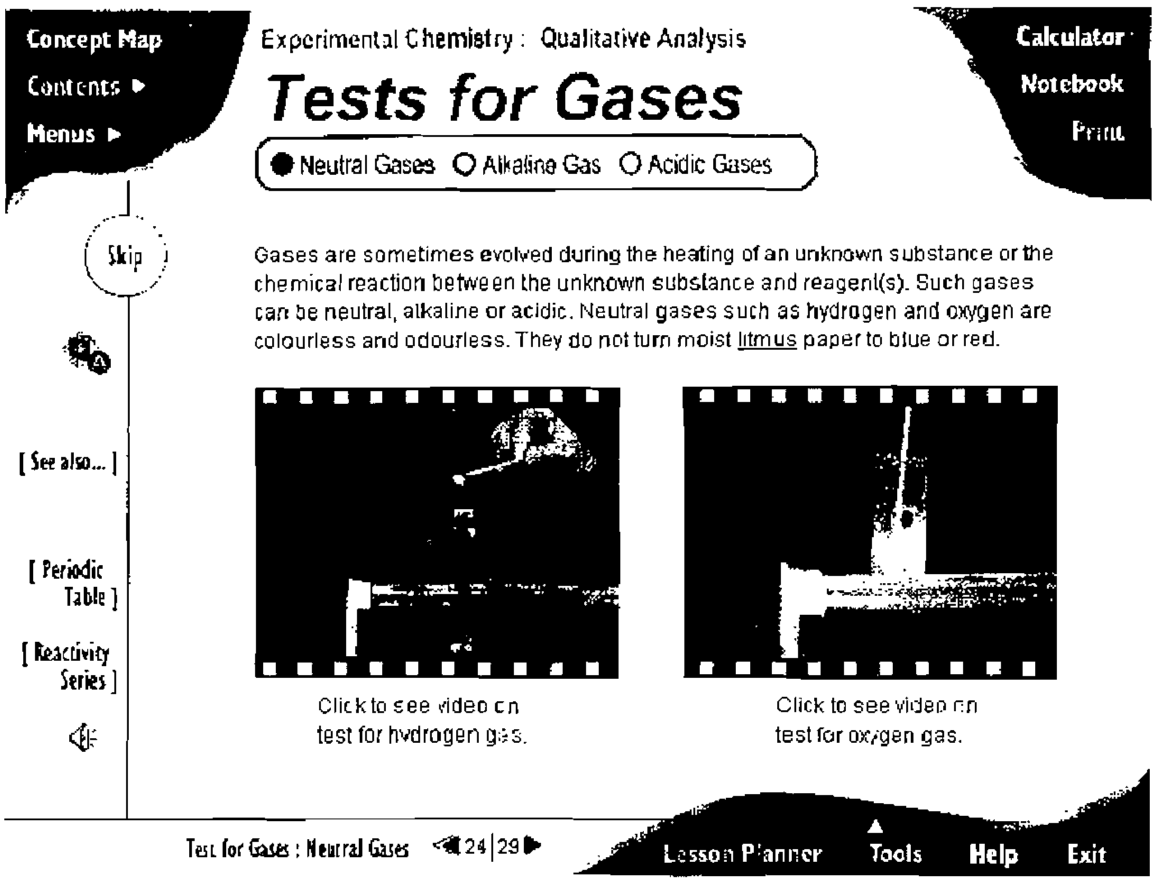

Figure 6. Experimental chemistry user interface

An example of a thinking skill that could be infused in the programme instruction of tests for cations and gases is experimental inquiry. This is a process of observing a macroscopic event of phenomena, analysing it to generate an explanation, making a new hypothesis based on the explanation, testing the hypothesis and re-evaluating the original explanation. Indeed, the learner could make new hypothesis before viewing the rest of the videos and then carry out the experiment to validate the hypothesis or in this case the results observed. Questions such as 'What do you observe?', 'How can you explain it?', 'What if ...?', 'How can you test your observations...?', 'What happened?' could be asked during the process of inquiry. This would certainly strengthen the understanding of the concepts. Figure 7 shows the graphic organizer that could be used for the process of experimental inquiry.

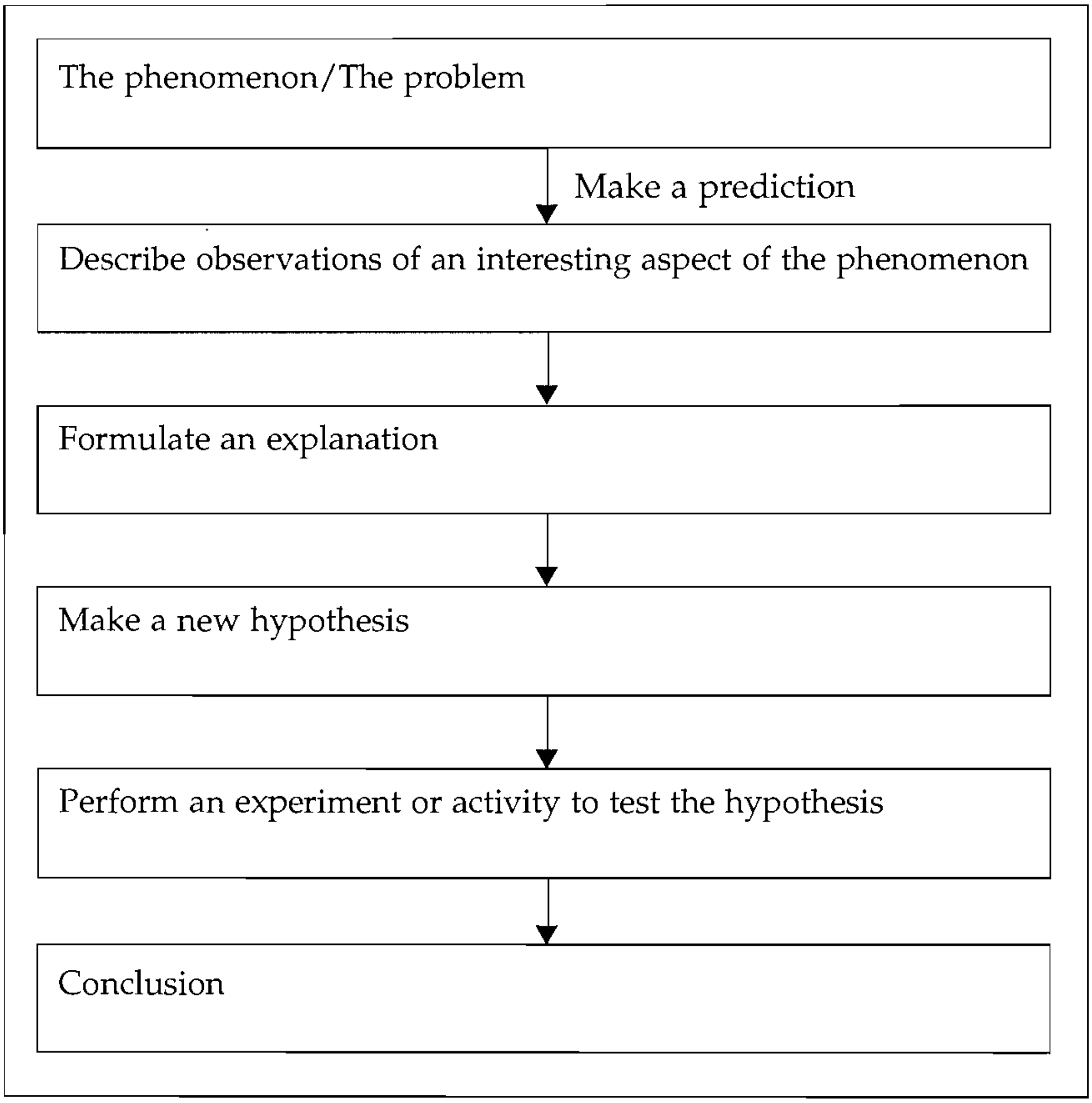

Figure 7. Graphic organizer for experimental inquiry

IMPLICATIONS

The beta tests of the product developed have been conducted with fifteen pre-service teachers (Year 3) taking a module on computer-based learning in chemistry under the Bachelor of Science with Diploma in Education degree course. In general, the evaluation of the product developed is found to be good and positive in the following aspects. Under presentation, information is presented in a developmentally appropriate and logical way. Examples and illustrations are relevant and there is appropriate variety in screen displays. The text is clear and printed in type suitable for the learners. Under program content, the instruction matches the stated objectives and the information is current and accurate. The instruction also addresses various learning styles and intelligences and the program is free of stereotypes. As for effectiveness, students are able to recall and use information presented following program use and that this is an appropriate use of instructional software especially in the exploratory activities. Besides, there is also positive feedback for the practice items, assessment, feedback and usability.

From what we have observed, visual graphical representations, for example concept maps, could be employed to show certain conceptual relationships and elicit thinking in the area of identifying patterns and relationships. Exploratory activities in the form of meaningful tasks could also be used to develop the processes of comparing, induction, deduction and prediction. Besides, video, an example of visualization, could be used effectively to help learners to perceive and process information thereby increasing the depth and fluency of observational learning as well as develop experimental inquiry (Carroll & Bandura, 1990).

Consistent visual cues to provide functionality, such as the purpose of the buttons, icons or menus; and feedback for learner actions, for example, the highlighting of buttons or icons when they are 'pushed' or 'clicked' to signal screen transitions, should be offered. General and system tools need to be strategically positioned for easy access to other features or information. As such, this would imply not only design for progressive disclosure (Apple, 1992) to reduce cognitive load but also design suitable coding mechanisms for effective dual coding (Paivio, 1979).

As such, the importance of content design will still continue to be of great importance even in the most advance created multimedia technological environment. Good and effective instructions are based upon the appropriate selection and proper organization of various instructional strategies that elicit processes, and not simply the medium per se. Indeed, learning via multi-modal instruction would improve when there is significant conceptual and temporal overlap between the information presented in each modality.

Finally, one also needs to consider the incorporation of the common features of an instructional system design ranging from determining and analysing the instructional goal; writing performance objectives to developing instructional strategies and designing and conducting evaluation in order to realize the full potential of such innovation in technology.

Mr Tsoi Mun Fie, Raymond, is a Teaching Fellow in Science & Technology Education Academic Group, National Institute of Education, Nanyang Technological University.

A/P Goh Ngoh Khang is an Associate Professor and Deputy Head in Science & Technology Education Academic Group, National Institute of Education, Nanyang Technological University.

A/P Chia Lian Sai is an Associate Professor in Science & Technology Education Academic Group, National Institute of Education, Nanyang Technological University

REFERENCES

Apple Computer Inc. (1992). *Macintosh Human Interface Guidelines.* Addison-Wesley.

Ben-Zvi, N., & Gai, R. (1994). Macro- and micro-chemical comprehension of real-world phenomena. *Journal of Chemical Education,* 71(9), 730–732.

Boyle, T. (1997). *Design for Multimedia Learning.* Prentice Hall.

Brotherton, P. W., & Preece, P. F. W. (1996). Teaching science process skills. *International Journal of Science Education,* 18(1), 65–74.

Carroll, W. R., & Bandura, A. (1990). Representational guidance of action production in observational learning: A casual analysis. *Journal of Motor Behaviour,* 22(1), 85–97.

Gabel, D. L. (1993). Use of the particle nature of matter in developing conceptual understanding. *Journal of Chemical Education,* 70, 193–194.

Grabe, M., & Grabe, C. (1996). *Integrating Technology for Meaningful Learning*. Boston, MA: Houghton Miffllin.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning, 7,* 75–83.

Jonassen, D., & Wang, S. (1993). Acquiring structural knowledge from semantically structured hypertext. *Journal of Computer-based Instruction,* 20(1), 1–8.

Mayer, R. E. & Anderson, R. B. (1991). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Psychology,* 84(4), 444–452.

Paivio, A. (1979). *Imagery and Verbal Processes*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Park, S. & Gittelman, S. S. (1992). Selective use of animation and feedback in computer-based instruction. *Educational Technology Research and Development,* 40(4), 27–38.

Shneiderman, B. (1997). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Reading, MA: Addison-Wesley.

Wilson, B., & Cole, P. (1991). A review of cognitive teaching models. *Educational Technology Research and Development,* 39(4), 47–64.

Wilson, B. G., Jonassen, D. H., & Cole, P. (1993). Cognitive approaches to instructional design. In G. M. Piskurich (ed.), *The ASTD Handbook of Instructional Technology,* 21.1–21.22. New York: McGraw-Hill.