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# Practical Multimedia Courseware Design for Learner's Difficulties in Chemical Education

by  
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## PRACTICAL MULTIMEDIA COURSEWARE DESIGN FOR LEARNER'S DIFFICULTIES IN CHEMICAL EDUCATION

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### ABSTRACT

The designing of multimedia chemistry courseware is a complex and challenging task for many instructional developers and writers especially in the initial stage of the prototype to be developed. As such, this paper provides insights gained into some practical design considerations in developing a multimedia courseware in chemical education at secondary school level. It concentrates on the early stage of the development process and specific design tips or guidelines based on practical pedagogical experiences in courseware design and storyboard. Among the seven major chemistry topics covered by the courseware as modules, two important modules, namely organic chemistry and experimental techniques are selected to illustrate some salient design issues that are related to certain important learning principles. The three understanding levels (macro, micro, and symbolic) related to learners' difficulties in learning chemistry will also be addressed in the development of the courseware. Implications for designing chemistry courseware, which emerge as a result of the design issues considered will also be discussed in the context of both the multimedia producer and writer.

### INTRODUCTION

In science and chemical education, three understanding levels have been identified (Johnstone, 1991; Gabel, 1993). They are (a) the macroscopic level, which deals with sensory/ visible phenomena such as laboratory observations and data; (b) the submicroscopic 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. Students have found it difficult to demonstrate transfer between the phenomenon and its atomic or molecular events and symbolic representations. Ben-Zvi & Gai (1994) have also suggested that teaching chemical concepts in the particulate nature of matter should emphasize the relations between these concepts and real world phenomena on both the macro and micro level.

Textbooks have attempted to provide enough symbolic notations associated with minimal images of either macroscopic or microscopic events leaving students to try to make sense of these images of chemistry from words, tables or graphs. As such, multimedia CD-ROMs integrating different presentation modes such as sound, text, images, graphics, and animations may be used to address this issue of the students' difficulties as well as limitations of the textbooks and also to allow students to be more exposed to the three levels of understanding. Multimedia is defined as a communication format that integrates several media – text, images, audio, video, and animation – most commonly implemented with a computer (Grabe & Grabe, 1996). 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.

Indeed, research in learning styles and "multiple intelligences" imply that some students learn better through specific presentation modalities, such as visual, audio, or kinaesthetic (Davis, 1991; Gardner, 1995).

### MULTIMEDIA DESIGN

In multimedia design, one of the important design considerations is not only to determine the goal of the instruction but also the pedagogical approach as well. A well-structured instructional plan will assist the designer (writer or developer) in areas of content organization, as well as content sequence and pacing. In terms of content, one needs to consider carefully relevant and useful materials that engage learners in meaningful authentic tasks (Wilson & Cole, 1991; Wilson et al., 1993). Indeed, designers are advised to take into account the importance of designing sequenced instruction, as this will allow learners to apply newly acquired knowledge to real world tasks directly.

With such design considerations in mind, a chemistry multimedia courseware is then developed using C++ programming language and Director 6. It aims to help students who take chemistry in their G.C.E. 'O' level. The current major topics or modules covered are experimental techniques; stoichiometry and mole concept; electrolysis; energy changes; chemical reactions; acids, bases and salt; and organic chemistry. The program presents the material using a combination of multimedia capabilities such as text, graphics, animation, and video clip to hold the students' interest and make the abstract chemical concepts more vivid. The "Guided Learning" approach is employed in the courseware. It guides students through a basic study of introductory-level chemistry topics at the secondary school level.

The following sections give an account of the early stage of the development process using flowcharts and instructional storyboards. Two chemistry modules, namely, organic chemistry and experimental techniques will

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be used to illustrate this early stage of development process with reference to certain important learning and design principles.

### *Design of Organic Chemistry Module*

Flowchart is an important element at the start of the development process especially for the multimedia producer as it gives an overview of the design framework within which system features such as general tools and system tools are to be incorporated. Figure. 1 illustrate this aspect by using different levels of organisation. It is important to note that the overall perspective of the framework needs to be consistent throughout the designing process.

In accordance to the learning principle that new knowledge will become more meaningful when integrated with existing knowledge (Gagne', 1985), structural devices are used. For example, in the introduction of the structure of the lesson, attention can be directed to relevant features. This will assist the users to access information selectively. Also, headings, an example of structural organiser can be used to help the users in distinguishing essential concepts from supporting ones. See Figure. 2.

Another learning principle is the way the concepts are organised, will influence learning (Mayer, 1984). As such, presentation stimuli, for example, text, visual, animation, audio will require meaningful integration not simply display as shown in Figure. 2. Such design and learning principles are to assist the students in understanding the three levels of understanding in science and chemical education at secondary school level.

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Level 2

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Level 3

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Figure 1. Flowchart

Also, learners can become disoriented when the procedures for accessing complex choices and information become difficult, or inconsistent (Steinberg, 1989; Beasley & Lister, 1992). As such, enough navigational aids are provided for users to find their way around with ease so that they will know where they are and locate specific information or overview of the structure of the courseware easily. Figure.2 illustrates this principle by devising easily accessible features such as visible buttons, icons, 'control panels', or menus which will provide the 'landmarks' to guide users. Such buttons, icons and menus will be highlighted or animated to provide users visual feedback that a choice has been made.

Figure. 2 also illustrates one of the learning principles for interface design that system features need to be logically organised, and functional to facilitate the learning process. Also, the important design principle of consistency have to be considered in many aspects of interface design. As such, proper screen design and navigational procedures that reduce the cognitive load on learners need to be created (Jacques et al., 1993; Sponder & Hilgenfeld, 1994).

For example, one can use familiar functional navigational icons, such as arrows to represent forward and backward movement; notebook to allow learners to use the electronic notepad; question mark to access the help menu; textual descriptions of icons that are 'activated' when the mouse is 'paused' over an icon; and so on.

<b>Date:</b> 16 Apr 99	<b>Previous:</b>	<b>Next:</b>	<b>Frame:</b> 1201
<b>Project Title: CHEM 'O' LEVEL Section: Alkenes (Reactions)</b>			
<b>Screen Display/Graphic/Text: Organic Chemistry</b>			
ALKENES			
REACTIONS			
ADDITION REACTION			
Alkenes readily undergo addition reactions in which smaller molecules or ions bond ("add") to the atoms on either side of the double bond.			
<b>Hydrogenation</b>			
<b>Ni Catalyst</b>			
$\text{CH}_2=\text{CH}_2 + \text{H}_2 \rightarrow \text{CH}_3\text{CH}_3$			
<b>Ethene Hydrogen 150° C Ethane</b>			
<b>(unsaturated) (saturated)</b>			
<b>Programming Instructions:</b>			
1. animation for reaction (both models) showing the breaking of double			

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**bond and hydrogen molecules adding to it.**

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

**General Tools: Periodic Table, Reactivity Series, Calculator, Notepad, Create lesson map, Print, Concept map.**

**Voice-over: Notice how the double bond of the ethene molecule breaks up & the hydrogen molecules add to it.**

Figure 2. Instructional Storyboard

The principle of progressive disclosure (Jones, 1989; Apple, 1992) is also employed. This involves keeping useful and relevant information within the multimedia learning environment presented to the learner in small, manageable coherent segments. This can be achieved through the provision of buttons that display a number of choices. As such, anxiety or frustration will be prevented since this will present only information relevant and available to the learners at any point in time.

As discussed earlier that since content organisation plays an essential role in the design of learning materials, there has to be a more meaningful integration of the different presentation stimuli to put across concepts in internally consistent and coherent segments. The principle in using animation that elicit effective visual and verbal information processing (Mayer & Anderson, 1991; Park & Gittelman, 1992) is considered in addressing the three levels of understanding in teaching or learning chemistry as shown in Figure 2 where animations are employed in a concrete way to depict certain molecular events.

An example of an authentic and useful activity to engage learners in meaningful tasks using process skills is shown in Figure. 3. Such activity will stimulate learner input and performance (Wilson & Cole, 1991).

Date: 16 Apr 99	Previous:	Next:	Frame: 2000
<b>Project Title: CHEM 'O' LEVEL Section: Activities (Exploratory)</b>			
<b>Screen Display/Graphic/Text: Organic Chemistry</b>  How unsaturated is the oil?			
<b>Programming Instructions:</b>  On enter of this frame, play Narration 1. (Introduction)			
1. EXPERIMENT: Animate procedures using apparatus such as conical flasks, dropper, hot-plate			
2. Materials : peanut oil or canola oil; corn oil or canola oil; coconut oil or sunflower oil			
3. My Prediction: ' Predict which oil will be the more saturated' Choice appears.			
4. My observations: (Expected Results) to be recorded automatically and correspondingly in the Notepad.			
5. Check Results: Food-Labels appear for comparison			
6. My Conclusion: e.g. There are higher amounts of unsaturation in fats in canola oil than in peanut oil, (canola than corn oil, sunflower than coconut oil)			
7. Introduction: Most animal fats are saturated hydrocarbons and are solids at room temperature, whereas most vegetable fats are unsaturated and are liquids at room temperature. Both types of fats are essential in our diets especially polysaturated fats and oils. Different amounts of unsaturation in fats can be compared by testing how quickly a red-brown iodine solution or bromine water added to each fat is decolorized.			
8. A pop-up window :Polysaturated means " containing many double and/ or triple bonds."			
<b>System Tools:</b> Help, Tools (Search, Glossary), Main Menu, Quit, Home, Return			
<b>General Tools:</b> Periodic Table, Flowchart, Calculator, Notepad, Create lesson map, Print, summary			

Figure 3. Instructional Storyboard

Conceptual organisation of content to be learned can be improved by using visual representations of lesson content and structure to show certain interrelationships among concepts (Jonassen & Wang, 1993). As such, in the development of this chemistry courseware, concept maps are used to show the conceptual relationships.

Active learning is also considered in the design of the experimental technique module. This requires the learners to go through the thinking process where one learns by processing information, by analysing, by classifying, by hypothesising and by generalising. Figure. 4 shows how active learning can be promoted through the different activities which reflect the rationale in using a particular separation method, that is the "what", "why", and "how" aspects of the technique (Merrill, 1988; Boyle, 1997). To reinforce the learning process, practice items within this motivating environment are provided.

The number of complementary presentation stimuli are increased to improve learning in which a variety of modalities such as visuals, audio, animation and text are integrated in a congruent and complementary way.

Date: 16 Apr 99	Previous:	Next:	Frame: 1801
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Project Title: **CHEM 'O' LEVEL Section: Expt Technique (Activity)**

Screen Display/Graphic/Text: Experimental Techniques

#### ACTIVITY

#### Programming Instructions:

On enter of frame, show picture I to vii in lab. setting & play narration 11 to 7vii respectively.

Upon end of Narration., Menu appears

1. Select correct answer, see feedback 1 in the form of text & narration 3.., and apparatus window appears.
2. Select wrong answer see feedback 2 in the form of text & narration2.
3. Select wrong answer the second time, see feedback 3 in the form of



text & narration 4.

4. Upon end of feedback 3 in the form of text & narration 4., apparatus window & menu appear simultaneously

followed by video & animation.

5. Select correct apparatus & feedback window appears followed by video & animation simultaneously.

6. Answers: (i) filtration; ii. Crystallisation; iii. Sublimation; iv. Separating funnel; v. distillation;

vi. Fractional distillation; vii. Paper chromatography

**Feedback:**

1. Very Good! \_\_\_\_\_ is the correct answer.

2. Sorry, that's not right! "Narration 1i to 7vii respectively" Please try again!

3. Sorry again! That's a good try! \_\_\_\_\_ is the used.

**Voice over:**

1. " Narration 1i to 7vii respectively. Choose the correct technique for separation."

2. "Sorry, that's not right! "Narration 1i to 7vii respectively" Please try again!"

3. "Sorry again! That's a good try! \_\_\_\_\_ is the used"  
Narration 1i to 7vii as follows:

1. i. We have two solids. Think about one being soluble in a solvent.

2. ii. We have both substances soluble in water. Think about they having different solubilities which vary with temperature.

3. iii. We have two solids here. Think about a special property.

4. iv. We have petrol floating on top of water.

5. v. how to obtain water from this solution?

6. vi. Is crude oil a mixture of substances of different boiling points?

7. vii. How to separate this mixture of two indicators?

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

**General Tools:** Periodic Table, Flowchart, Calculator, Notepad, Create lesson map, Print, Summary.

Figure 4. Instructional Storyboard

## IMPLICATIONS FOR DESIGN

The development of multimedia chemistry courseware presents both the writer and multimedia producer with a number of challenging tasks. The primary goal here is to assist students to learn chemistry in a multimedia learning environment where the three levels of understanding (macro, micro, and symbolic) need to be taken into account and emphasised wherever possible.

The importance of content design will continue to be paramount even in the most advanced created multimedia technological environment. Instructions need to be logically sequenced to accommodate a wide variety of learning styles. There should also be the design of meaningful real world or authentic tasks as well as provision of appropriate constructive feedback.

Visual graphical representations, for example, concept maps can be employed to show certain conceptual relationships. Animation, an example of computer graphics, can be used effectively to help learners to perceive and process information thereby increasing the depth and fluency of learning. Equally important is the pedagogical approach in the design of the multimedia courseware, which needs to be selected and understood. This will call for a number of learning theories of psychological foundation to be examined and organised appropriately into a framework for design decisions which is another issue that is not within the scope of this paper.

From what we have observed, it is clear that the production of chemistry multimedia courseware generally requires a spectrum of skills and a substantial investment of resources, to the extent that this mammoth task cannot possibly be carried out by an individual. This will mean that interdisciplinary design teams of members ranging from technical writers to user interface designers to quality assurance experts will emerge inevitably.

Indeed, it is important to elicit different perspectives on the same multimedia product as this will enhance the educational value of the product. Hence, courseware development is not a one-way process with arrows going in one particular direction through a flow chart, but rather an iterative process. Social negotiation in the form of ongoing, detailed, and critical dialogue has to be initiated by both the multimedia producer and the writer. As such, flowcharts to give the conceptual overview and instructional storyboards to convey the visualisation of the topic or sequence in instructional media need to be constructed carefully and agreed upon.

In looking at the early stage of the development process, it seems that the principle of consistency plays an important role in screen and interface design. 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. Text are to be kept short, preferably, a maximum of 75 words per screen while text should be segmented into logically organised units. General and system tools need to be strategically positioned for easy access to other features or information. Hence, this will imply design for progressive disclosure.

Despite the complex nature of chemistry multimedia courseware design, technological advances are providing dynamic new design and development opportunities. However, the development of sound pedagogy based on educational theories is still of primary importance. As such, careful considerations of issues as who the learners will be; what type of system the program will be operating on; how best the learning materials will be organised and structured; what kind of user interface design will be designed; and how best the design and development process to be approached; need to be fully addressed to realise the potential of such multimedia courseware.

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