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Design elements for interactive multimedia

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An educator involved in interactive multimedia (IMM) development faces two significant problems. The first is how to transform what is already known about what constitutes good teaching practice into IMM. The second involves understanding one's own personal theoretical perspective on learning, a perspective which influences everything one does as an educator, both in the classroom and during activities such as designing IMM. We need a framework which links pedagogical perspectives on teaching and learning to strategies for designing specific interactive multimedia elements related to particular desired educational outcomes. In this paper we develop such a framework. It is our hope that IMM developers will be able to use this framework, both in reflecting on their current teaching practice and IMM designs, and in considering future directions for their work.

1. Introduction

In the past implementation of a new curriculum or designing an innovative approach to teaching an existing curriculum involved examination of the literature in the content domain and reviewing instructional strategies to evaluate what were the difficulties experienced by students, peer review of the sequencing of content, and examination of other similar curricula. In our opinion, the design of interactive multimedia in higher education has often developed with minimal reference to the educational research available, both within a particular discipline and about student learning in general. This is in sharp contrast to the manner in which most researchers in higher education normally undertake a research activity. Instead, development of IMM has tended to focus on the hardware (e.g. which platform, CPU clock speeds, delivery platform verses development platform) and software (e.g. screen design, development tools, the use of colour, navigation, and budget and time restraints) issues rather than the educational perspective.

One of the major difficulties in the design of IMM is the gulf between the instructional or educational design of IMM and what the research literature indicates is good teaching practice. Ramsden (1992) lists a number of features that have been shown to be appropriate strategies for effective learning (p. 89):

- Good teaching practice
- Emphasis on independence
- Clear goals
- Appropriate assessment
- Appropriate workload

These five categories have been extensively trialed through the use of the Course Experience Questionnaire (Ramsden, 1991) and have been shown to be reliable and valid performance indicators for teaching quality in higher education. In section three of this paper each of the five categories are examined and the relationship between good teaching and IMM design is explored. Examples of IMM design that illustrate the practice are given along with examples of existing software that illustrate the design principles discussed.

2. Teaching and learning

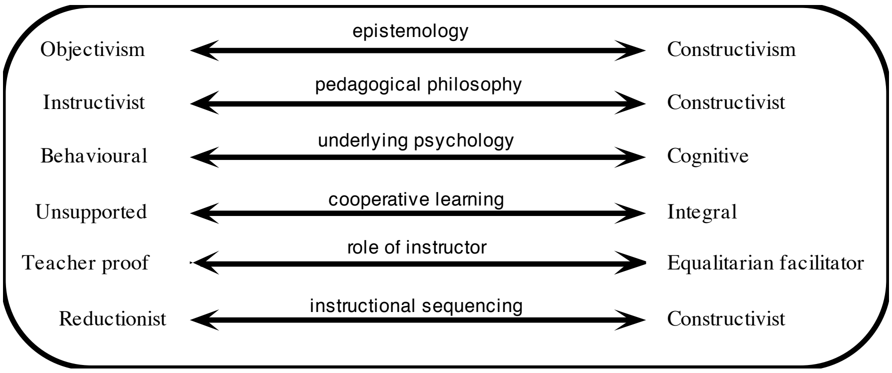
Learning is the way in which an individual changes the way s/he conceptualises the world. Teaching involves a lecturer constructing learning opportunities for students. The teaching methods chosen as the focus of the learning opportunities, teacher-centred or student-centred or a mixture of both, are strongly influenced by the educational beliefs held by the lecturer. This paper is concerned with how these perspectives are applied to the design of IMM. Traditionally the settings for academic learning have been in the form of lectures, tutorials, practical classes, problem solving exercises and assignments. The development of IMM for learning has generally been seen primarily as an extra learning opportunity for students, either in the form of a self-paced tutorial done in the student's own time or as an aid to revision. Only limited examples exist where IMM has replaced part of the traditional approach to academic learning in higher education.

In order to build a more complete theoretical framework it must be recognised that the value of any piece of IMM can only be considered within the total context in which it is used. IMM is just one of the strategies effective teachers may use in designing a curriculum for their students.

What we may consider to be a good IMM design may not be used to its full potential, while software perceived as merely adequate may be used with great effect. Laurillard's (1993) four processes are valuable here in deciding how actively students are engaged in their own learning. These four processes are:

- *discussive;* the learner and the teacher negotiate the goals of the task, in that the teacher provides descriptions of the task which are meaningful to the learner, while the student articulates an understanding of the task;
- *interactive;* the learner acts to achieve the task goal while the teacher provides intrinsic feedback relevant to the task;
- *adaptive;* the teacher evaluates the 'distance' between learner and the intended goal and suggests tasks to achieve said goal; and
- *reflective;* the teacher provides support to facilitate the learner's reflections on achievement levels.

The design of IMM has many facets, not least of which are the pedagogical and epistemological views of the teacher or lecturer. Reeves (1992a) developed a pedagogical model of instructional design in order to provide a more informed basis for communicating and understanding the features that an IMM designer might incorporate in software. A component of Reeves' model is shown in Figure 1; the full model has 14 dimensions.



(after Reeves, 1992a, p.110)

Figure 1: Reeves' pedagogical model of instructional design

The implication of Reeves' work is that IMM designed from perspectives of teaching and learning represented by the right-hand list (a constructivist perspective) in Figure 1 may lead to a more active learning environment for students. Henderson (1994) points out that this may be true for many situations; but a constructivist perspective means that knowledge is socially and culturally constructed, and cultural perspectives on knowledge may differ markedly. A culturally inclusive approach should be used in IMM design; as noted earlier, it is essential to consider both the design and use of IMM within particular educational contexts.

Aspects of Reeves' pedagogical model

Epistemology refers to theories of knowledge. For example, an objectivist IMM designer would attempt to construct software to transmit the laws and truths of any particular content domain to the student. However, constructivist epistemology allows for multiple perspectives of a phenomenon from which students construct their own knowledge.

The approach to teaching and learning is reflected in a designer's pedagogical philosophy. Instructionists derive their teaching strategies from behavioural psychology: the learner is a recipient of instruction; content is prescribed and instructional strategies focus on delivering the content and covering the course. Conversely, constructivists focus on the learners' prior knowledge and mental models. The learning environment is made as rich as possible to enhance students' ability to construct knowledge and resolve conceptual difficulties. The emphasis for a constructivist IMM designer is to build learning environments which can be adapted to the specific needs of individual students and actively engage the student in constructing new knowledge.

The underlying psychology of IMM design may be viewed from either a behavioural or a cognitive aspect. The behavioural view asserts that it is not the internal constructions which are of importance, instead it is directly observable behaviour which is important (Farnham-Diggory, 1972). In IMM design this leads to a stimulus (a short piece of text), a response is elicited (in the form of a question) which results in feedback (the accuracy of response given), followed by positive reinforcement (for correct answers) (Reeves, 1992a). The cognitive perspective, however, focuses on the internal mental constructions of the learner and attempts to provide learning opportunities for the student to address conceptual difficulties.

Effective learning does not occur in a social vacuum. Cooperative learning may be integral or absent in IMM software. The potential for cooperative learning occurs when the IMM software is designed to be used by either pairs or small groups of students. For example, the undergraduate chemistry software, ChemCAL (McTigue, Tregloan, Fritze, McNaught, Hassett, & Porter, 1995) may be used by either one or two students. On startup the program requests two names, and at the conclusion generates a joint report. There is support (e.g. Johnston & James, 1995) for the idea that many students find that cooperative learning strategies assist their learning.

The role of the instructor or teacher in the use of IMM programs in some contexts has been reduced to a minimum. A hidden agenda of such systems may be to prevent teachers' pedagogical beliefs from undermining the intent of the program (Reeves, 1992a). This is a common theme in systems designed from studies into artificial intelligence (Perez, Gutierrez, & Lopisteguy, 1995).

Instructional sequencing and the degree of learner control reflect the conceptions of teaching and learning held by a teacher. A constructivist designer adopts the view that a high degree of learner control will enhance learning opportunities by allowing the student to access the material in a manner more suited to her or his own needs and interests. This model of design provides students with rich content and many navigational opportunities. The problem with this approach stems from the size of some hypermedia programs; there are so many possible paths the learner becomes lost-in-hyperspace (Perez, Lopisteguy, Gutierrez, & Usandizaga, 1995). Clear navigation is essential. However, the reductionist perspective is to transmit the required content to the student. Topics are organised into hierarchies by content experts. Students receive the material in the order prescribed and all students are expected to learn in the same way.

Reeves' pedagogical model is consistent with Biggs' (1989) model of deep and surface learning, and has implications for teaching strategies which result in particular learning outcomes in students. These strategies are represented in Figure 2. Biggs (1989) perceives that the motives and strategies adopted by students for a particular learning task may be seen as their 'approach' to learning. Students who adopt a surface approach focus on learning the facts and reproducing them accurately. Students with a deep approach are intrinsically interested in the topic of study, tend to maximise their understanding by reading widely, discussing the concepts with peers and tutors, and reflecting on how their new knowledge may be integrated with what they already understand.

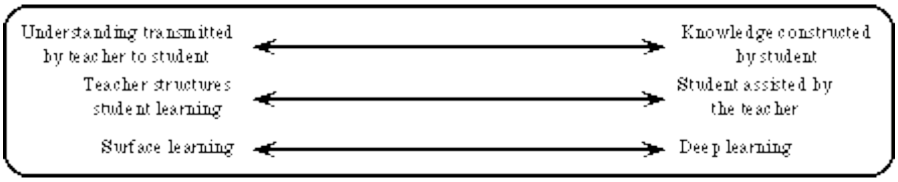
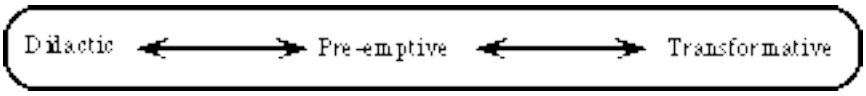


Figure 2: Implications for teaching and learning

One group of teachers adopts teaching strategies based upon didactic/ transmission/ reproducing/ expository methods and use teaching strategies represented by the terms on the left of Figure 2. There is a second group who perceive learning as knowledge construction by the student, where the teaching strategies are intended to engage the student in actively constructing their own knowledge in order to develop a deeper understanding of concepts-represented by the right side of Figure 2. The process of knowledge is complex, involving both the refinement and deepening of the understanding of particular concepts and the use of the richer understanding gained to construct new interpretations and frameworks of the content domain. The intent is to engage students in a transformative/ conversational approach to learning in order to refine and assimilate understanding (Laurillard, 1993). The two groups attempt to design IMM with different strategies or learning opportunities (elements) which have the potential to engage students in a variety of ways.

However, there is also a third group represented by teachers who are sensitive to past students' learning difficulties and perceive that their role is to offer better explanations of difficult concepts (Bain & McNaught, 1996). This group tries to pre-empt the problematic concepts there is a genuine concern for student learning but the control of the learning, and often the responsibility for the learning, rests with the teacher. Teachers with a pre-emptive view of teaching and learning design IMM with on-line glossaries, hints and explanations to help guide students through the software. These educational beliefs are represented in Figure 3.



(after Bain & McNaught, 1996)

Figure 3: Lecturers' educational beliefs

While some IMM designs are clearly based upon didactic, pre-emptive, or transformative conceptions teaching and learning, IMM is only part of the context in which teaching and learning occur (Laurillard, 1993; Wills & McNaught, 1996). The cognitive load on students is often higher with IMM based on transformative conceptions of teaching and learning. Teachers may well simplify the intended use so that students are not so actively engaged. Conversely, quite simple software, such as a linear instructional sequence or a basic database, can be used in highly interactive settings—where the activities (questions, problems, tasks) designed by the teacher for use with the software have the potential to actively engage students in transformative dialogue and construction of new knowledge.

3. Pedagogy and design: Some examples

The framework presented here will attempt to show how IMM can address good teaching and learning practices which aim to engage students in active rather than passive learning, through a transformative rather than a pre-emptive or expository model of design. In Table 1 we have attempted to show how different conceptions of teaching and learning are likely to lead to the inclusion of particular design elements in an IMM project. How a particular interactive multimedia program utilises the elements outlined in Table 1 will depend upon:

- the educational objectives which guide the design of the software;
- the software tools chosen to construct the IMM; and
- the context in which the software will be used.

One challenge for IMM developers is to reflect on their own views about teaching and learning. A number of questions arise.

- Which model of learning is congruent with their educational objectives?
- To what extent might developers wish to shift their educational views?
- What are the implications for course and materials design that any shift in teaching strategies might have?

Table 1 is presented in the hope that it provides a tool for the educational component of the design of IMM software. It attempts to relate the educational perspectives of the designer to elements which might be incorporated as a result of those beliefs into any particular project. Therefore, a major purpose of the table is to provide teachers and lecturers with the facility to match the desired educational outcomes of an IMM project with the elements which have the greatest potential to achieve those outcomes. For example, studies from many institutions over a period of many years "have drawn attention to the wide gap between the rhetoric describing the qualities lecturers say they want in their students' responses, and the tasks they set" (Biggs, 1989, p. 15). It is hoped that the articulation of this framework will assist IMM developers in consciously reflecting on their own educational conceptions and will broaden the range of IMM design elements used.

3.1. Good teaching practice

In the discussion that follows, we have taken each of the descriptors that Ramsden (1992) used for each of the five criteria for effective teaching and learning. Clearly, there is overlap between these descriptors and indeed between the criteria themselves; we do not intend that the framework be taken too literally, but rather that the discussion and examples cited will stimulate reflective thought in this area.

3.1.1. Showing respect and concern for students

Both 3.1.1. and 3.1.2 refer to attributes of teachers, not of software. The relevance to the topic of this paper is that appropriate use of IMM can be perceived by students as staff really caring about the nature of their learning experience. Students appreciate the effort made by academic staff in the preparation of IMM courseware (and conventional multimedia materials, course outlines, solutions to problems, etc.). They perceive that IMM is being designed to enhance their learning opportunities. Such perceptions can raise students' motivation levels markedly. IMM that contains an on-line help and/or glossary can be used as an attempt to recognise individual student needs.

3.1.2. Sharing the love of your subject with students

At first glance, these social factors may be considered problematic when using a computer as a cognitive tool. However, research indicates that students perceive that teachers and lecturers who make an effort to make their subject more interesting, more accessible and more enjoyable by using IMM are respected and appreciated for their efforts (McTigue *et al.*, 1995). A formative design process that involves teachers, students and instructional designers in meaningful discussions about the nature of learning can enhance the design of IMM.

3.1.3. Being able to make the material to be taught both interesting and stimulating

Initially, computer software consisted of drill and practice derived from a text-based format. As the hardware and software tools became more powerful, IMM utilised text, animation, graphics, sound, and video. Early instructional design in IMM limited the opportunity for students to interact with, or sequence the content. Arguably, IMM is enhanced by creative uses of multimedia (avoiding electronic page turning, incorporating high degrees of interactivity). However, the content, and the sequence in which it was organised was often prescribed by either a content expert or the programmer. Limited thought was given to differences between learners (e.g. prior knowledge or individual learning styles). Learners had little control over the sequencing or the style of their learning. The commonly used click-and-point interface also diminished the ability of students to gain their own perspective on the content. Increasing learner

Criteria for effective teaching and learning (Ramsden, 1992)	**Didactic or trans-mission modes of IMM design**	**Pre-emptive modes of IMM design (Bain & McNaught, 1996)**	**Transformative or conversational modes of IMM design (Laurillard, 1993)**
Good teaching practice • showing respect and concern for students • sharing the love of your subject with students • being able to make the material to be taught both interesting and stimulating • engaging students at their level of comprehension • explaining the content using clear and appropriate language • improvising and adapting to new demands, • learning from students and other sources (e.g., journals, colleagues) about the effects of teaching and how it can be improved	The traditional lecture is often characterised by poor teaching practice. While individual lecturers are passionate about their subject, student learning may be passive rather than active, adaptation to new ideas can be generally slow and student engagement can be minimal. IMM designed within a didactic model may have: • the content and sequencing prescribed by the lecturer • relatively little student activity—books on screens • minimal credence given to alternative models of representing knowledge; one right answer	Pre-emptive models of IMM design acknowledge the student as fundamental to the design of the program. The use of the 'better explanation' is a defining feature. • use of appropriate language • on-line help and glossary • formative evaluation in design process • multiple perspectives of concepts • multiple paths through the software or a greater degree of student control • design of animations, etc. based on misconceptions • adaptive hypermedia (navigation, presentation) • use of life-world experiences of student • attempts to actively engage students in modes of problem solving • good use of visual and audio material	Transformative indicates an iterative approach to learning through the processes of discussion, adaptation, iteration and reflection. The challenge is to design IMM to respond to the different learning styles and needs of the students. A suitable context in which the IMM can be utilised is essential to the design. Most of the elements listed under the 'pre-emptive' column are also appropriate here. Others are: • encouraging development of a personal perspective • questions aimed at conceptual change (conflict) • tasks which allow students' to build their own representations • students negotiating tasks • use of communication technologies for discu-ssion and negotiation • linkages to other parts of the T/L context in which IMM is embedded • good use of visual and audio material, often associated with multiple represent-ations of concepts
Emphasis on independence • providing opportunities for students to become more independent • implementing teaching techniques that require students to learn actively, act responsibly and operate cooperatively.	• There is little or no opportunity for students to be independent in this model of IMM design. • only one navigational path • passive learning, characterised by click-and-point interfaces • minimal learner control	There is considerable effort made to engage the learner in active learning. • IMM provides alternative paths for navigation which attempt to address different learning styles in students • activities involving problem solving may be present • software may be designed to be used in groups rather than with individuals	The focus is to make students metacognitive about their own learning processes. • the content may be sequenced by the student • the software is integrated with a specific context which promotes an iterative discussion process • cooperative problem solving

Clear goals • being committed to explicating what must be understood, the level of understanding and why this level is appropriate, • valuing understanding rather than rote learning	In traditional lectures the syllabus outline was generally provided however the level of understanding and why it is required were not made clear. • IMM focuses on browsing rather than engagement in relevant tasks • statements that understanding is valued and desired; however, the designs don't foster such outcomes	Active efforts to integrate the goals with the content of the IMM. • hypertext links from text, exercises and interactions to the syllabus outline • good explanation of goals • a clearly articulated desire for more than surface learning • on-line frequently asked questions	The student is engaged in the shared determination of the goals of the academic content. • engagement in construction of relationships linking goals to academic content • hypertext links from text, exercises and interactions to the syllabus outline • relationships between prior, current and future course directions are explicated
Appropriate assessment • applying appropriate assessment methods, the purpose of which are clearly understood • giving feedback of the highest quality on student work	Early CFL was characterised by either multiple choice or one word answers. • predefined (algorithmic) relationships between student responses and feedback, or • feedback is limited to yes/no or right/wrong answers, or • limited feedback (e.g., a statement of the algorithmic answer to the problem)	This mode focuses on multiple methods of assessment but is still characterised by multiple choice or one word answers. • problems related to the 'better explanations' provided • immediate feedback	Assessment is focused upon determining the level of understanding and explicating personal perspectives representing the academic content. • extended answers which may be self-assessed from a number of models of expert answers • multiple modes of assessment • the student may negotiate the modes of assessment with the academic
Appropriate workload • focusing on key concepts, and students' alternative frameworks, rather than on just covering the ground	The general process is on delivery of the course and covering the material. In IMM this results in • only including the prescribed academic content • no allowance for negotiated timelines	The focus is on addressing students' prior knowledge and misconceptions rather than just covering the ground. • the workload is adjusted. IMM is not merely an adjunct to conventional lectures, tutorials or practicals	The focus is on key academic concepts in consultation with students. • outcomes and timelines are negotiated and students are focused on developing relationships between key concepts within an appropriate time period • flexible use of communication technologies to achieve balanced workload

Table 1: Relationships between criteria for effective teaching and modes of IMM design

control is likely to improve student motivation and interest in the content. Also, the use of life-world experiences of the learners (where possible) in IMM design stimulates the learner to develop knowledge from a more personal perspective. Decontextualising content does not encourage a deep approach to learning.

3.1.4. Engaging students at their level of comprehension

Ramsden argues that a single prescribed path through the program, imposed by the 'content expert' or 'instructional designer' would seriously inhibit students' access to the content and the potential for higher levels of cognition. Therefore, IMM should provide opportunities for students to access the content in a highly individualised manner (Reeves, 1992b). IMM design needs to address issues of how the learner may want to think about or study the content. To enhance student interest and engage students at their level of comprehension, students' prior knowledge should be included as part of the content of the IMM (Ausubel, 1968; Kennedy, 1995b). Students' prior knowledge includes life-world experiences appropriate to the content, previous studies in the content area, and alternative frameworks already developed.

The work of Alexander and Cosgrove (1995) looks at students' prior knowledge, and then confronts them with their strongly held prior knowledge constructions, ultimately challenging them to defend their beliefs over the scientific view of electricity. This IMM program adopts a conversational, transformative model of learning. Alexander and Cosgrove (1995) argue that transmissive models of teaching often force students to operate algorithmically because students are denied the opportunity to generate their own understandings of concepts through the normally iterative process of scientific discourse. Instead, their approach is one that attempts to align students' personal theories with scientific theory. Students' prior knowledge constructions are very resilient to change and students must unravel the reasoning that led them to their current understanding and construct a new personal view of the concept domain.

In *StatPlay*, Thomason, Cumming and Zangari (1995) use multiple representations of statistical concepts to encourage students to immerse themselves in microworlds. In *StatPlay* students may approach statistical concepts from multiple perspectives in order to develop congruent understandings.

3.1.5. Explaining the content using clear and appropriate language

Scientific knowledge has often been stated as being 'counter intuitive' (Wolpert, 1993). This view is supported by Resnick (1989, p. 5) who argues that "basic scientific concepts are in fundamental epistemological conflict with many commonplace everyday conceptions”. These two views reflect our experiences of teaching and learning. Students’ prior knowledge of a particular content domain often contains many alternative frameworks and uses language in a non-precise form. Kennedy (1995a) indicates that students use everyday language and expressions to describe scientific concepts. These expressions are often imprecise or exhibit alternative frameworks. For example, in a study of high school students studying a pre-university chemistry course, students often used the word ‘heat’ when ‘temperature’ would have been more appropriate, and in some instances they described physical processes in terms which indicate they believed a chemical processes had taken place (Kennedy, 1995a).

The IMM designer’s tasks are to determine the appropriate language to be used, provide an on-line glossary, help files with examples of procedural approaches to problem solving, and multiple perspectives of concepts.

3.1.6. Improvising and adapting to new demands

This is one of the most difficult issues facing developers of IMM today. An experienced teacher is able to monitor the understanding of the learner very closely (appropriate questioning techniques, direct observation of student practice and responding to student questions) and adapt his or her instructional strategy as appropriate. With careful design and a sufficiently large database, IMM can be produced which adapts to the user’s individual needs and interests. Brusilovsky and Schwarz (1997) have designed and implemented an Adaptive Hypermedia Systems (AHS) in a project called InterBook (an authoring system for designing Web-based adaptive hypermedia) which uses concept-based navigation to adapt the navigational support provided for the student depending on the individual differences, prior knowledge or navigation constructions that develop as she or he uses the software. The AHS builds a model of the goals, preferences and knowledge of the individual user and then uses this information to adapt the hypermedia to suit user needs. It is designed to support student-driven exploration of educational content.

With adaptive presentation, an initial questionnaire is provided for students and the information gathered is used to alter the on-screen material. The information gathered includes the semester the student is currently in, and the purpose for using the hypermedia (exam preparation, introduction to the topic, and the bias the student wishes to apply to the content). An example of this type of software is ANATOM-TUTOR (Beaumont & Brusilovsky, 1995). With this example, however, the student models are based upon the premise that students have already mastered the previous content. Much of this research is driven by studies into Artificial Intelligence (AI) and neural networks. In these areas of study the aim is to develop software that can mimic or extend the functionality of an expert teacher. Thus far, the systems described above rely on algorithmic design parameters in order to either modify the navigational paths or the content of the software viewed by different students. It is important in evaluating the potential uses and benefits of adaptive systems such as this to recognise the assumptions about student learning that designers of these systems have. The idea that suitable pathways can be uniquely determined for a learner is problematic; however, such systems can be used to suggest pathways for students without precluding students choosing other alternatives. The tension between computer-based *adaptive* systems and learner-centred *adaptable* systems may well be lessened with a shift from monolithic 'intelligent' tutors to smaller 'intelligent' agents (Boyle, 1977, p. 62).

3.1.7. Learning from students and other sources (e.g. colleagues, journals) about the effects of teaching and how it can be improved

A number of researchers have experienced surprise (Dickinson, 1994) when confronted with the interpretations and understanding expressed by students asked to provide feedback for IMM (McNaught, McTigue, Fritze, Tregloan, Hassett, Whithear, & Browning, 1995). Research has indicated that a formative, iterative design process which involves students produces more useable and effective IMM. Lecturers and teachers need to be reflective about their teaching practice, and beliefs about teaching and learning. In IMM design this involves providing a mechanism for the students to provide feedback (preferably screen by screen) regarding all aspects of the interface design-content, screen display, navigational options, animations and the response of the software to actions by the learner.

An existing IMM resource at The University of Melbourne is the set of *ChemCAL* modules (McTigue *et al.*, 1995). *ChemCAL* uses on-screen video and animations, a range of question formats and three levels of direct response to students; it also has built-in logging that provides two-way feedback to both students and course supervisors. Every screen is designed to allow students to comment on any aspect of that particular screen. In addition there is a more extensive form at the conclusion of the chemistry content where students may make more detailed comments about the package. The formative and summative evaluation done on these materials indicates that the students like using the software and achieve similar or better academic results in examinations (McNaught *et al.*, 1995). The formative evaluation of the software from the students' perspective encouraged many alterations to the design of the final product.

3.2. Emphasis on independence

3.2.1. Providing opportunities for students to become more independent

As stated above when students are given control of the learning materials they exhibit a wide range of navigational routes. Some begin by looking at what they already know while others start with unfamiliar concepts and principles. Some work though the materials in a linear fashion, while others leave an exercise half done to explore another section before returning to complete the initial exercise (Laurillard, 1993). Clearly learners require a range of navigational opportunities in order to facilitate their own style of learning. The work of Pérez *et al.* (1995) is an example of adaptive IMM which addresses student learning styles and prior or current knowledge structures. They have designed a system that has adaptive navigation and content, based upon a profile of student's learning with the software. There is some evidence that students (McNaught, Browning, McArthur, Prescott and Whithear, 1977) want to have freedom of navigation but also have preferred pathways indicated; in other words, they wish to have some support in learning how to make sensible independent choices.

3.2.2. Implementing teaching techniques that require students to learn actively, act responsibly and operate cooperatively

The goal of good IMM should be to involve the student actively in the construction of knowledge. Most current researchers would regard the notion of 'click and point' in software as being only marginally interactive. Sims (1994) has suggested that there are seven levels of interactivity, consisting of passive or electronic page turning, using hierarchies, updating, constructing, using simulation, using free interactivity, and being actively situated. The levels have implications for:

- the way in which learners interact with an application;
- multimedia design and development; and
- the link between learner control, interaction and navigation.

Knowledge construction by students requires software that allows students to actively construct knowledge. Interactivity may be enhanced by using problem solving exercises, case study scenarios, or interactive experiments. The microworld software *Exploring the Nardoo* (Interactive Multimedia Learning Laboratory, 1996), in which students explore water resource problems in a field study centre and along a river, illustrates the nature of situated learning in which the students are actively involved in constructing their own knowledge (Hedberg & Harper, 1995). Interactivity in the Nardoo software has been designed with situated learning as a major premise—in that "the activity in which knowledge is developed and deployed is not separable from or ancillary to leaning and cognition, but an integral part of what is learned" (Brown, Collins, & Duguid, 1989, p. 32).

3.3. Clear goals

3.3.1. Being committed to explicating what must be understood, the level of understanding and why this level is appropriate

Providing clear educational goals within an IMM learning environment is a straight forward process involving the inclusion of suitable text-based materials. Surprisingly, it is not often done. However, IMM designs allow for not only the provision of program outlines but hypertextually linked content within the program itself. The opportunity exists for good IMM to have interactive linkages that relate the academic content of the software to the goals the students are expected to achieve. Good IMM should therefore contain a syllabus outline which is linked by hypertext to the content, questions and exercises in the software. Sound instructional design of IMM also has the potential to display to students the relationship of the current academic content to prior and future work in the subject domain.

3.3.2. Valuing understanding rather than rote learning

Models of IMM design which facilitate the construction of students' knowledge are more likely to encourage deep learning with associated understanding. Mayes, Kibby and Anderson (1990) have developed learner support environments which involve dynamic hypertext linking called *StrathTutor*. Students have the opportunity to examine hypotheses to develop relationships between the attributes of a system. Students may interrogate the software by developing a hypothesis with particular attributes. The system responds according to pre-defined attribute coding, offering the student a 'guided tour' of all screens that are coded with that particular set of attributes. The student is able to dynamically form hypertext links appropriate to their learning needs. This model of software design is potentially transformative as it allows students to actively construct their own knowledge and develop hypotheses.

3.4. Appropriate assessment

3.4.1. Applying appropriate assessment methods, the purpose of which are clearly understood

IMM should explicate the model of assessment presented in the software, the purpose for which it is designed (formal assessment, mastery learning, or informal feedback for the student), and the number and type of questions the student will experience in using the software. The model of assessment often drives the type of learning required by the student. Short answer, and one-word answer assessment items are more likely to foster a shallow-rote learning approach in the students since such questions tend to address knowledge-based questions rather than involve problem-solving, analysis or synthesis. There are many methods available to IMM designers for assessment. They include:

- providing opportunities for extended answers within the software to be entered by students, which may be then down-loaded to the tutor or lecturer;
- on-line facilities to email the tutor or lecturer with problems or questions; and
- paper-less submission of assignments.

Studies in Artificial Intelligence by Dowling and Kaluscha (1995) and Petrushin, Sinitsa, and Zherdienko (1995) have suggested methods of providing computer-based adaptive assessment of student knowledge. This work is predicated on predefined relationships within a knowledge hierarchy as defined by content experts. Students are provided with questions from a large database of items. The student response guides the response of a software algorithm in selecting the next test item. This area of research is focused specifically on designing alternative procedures for elucidating and grading student knowledge: the number of possible relationships in a given hierarchy increases exponentially with the number of items in the database of questions (Dowling & Kaluscha, 1995). This method of assessment largely follows a model of pre-emptive design. The students do not have the opportunity to negotiate goals or the nature of the assessment model.

3.4.2. Giving feedback of the highest quality on student work

IMM can provide timely (when the student wants it) and iterative feedback for the user (Marchionini, 1990). IMM can also provide the basis for individualised student feedback by the use of an iterative approach to the design which allows the on-line help and the basis for the feedback to be constructed from typical student questions and problems. Also, IMM software can provide model answers for students. For example, a student may be required to provide an extended answer to a particular question. Once the student enters an answer, s/he could be provided with a number of model answers to the same problem. This approach provides both immediate feedback and a form of self assessment that is difficult for a lecturer to provide in all but the smallest class groups.

Another example, the software *mark* and its successor, *xmark*, developed by Ho and Whale (1995) is designed to both assess student work and facilitate student feedback on-line. The software *xmark* is able to accept documents from students which contain text, diagrams, sound, and movie objects. The tutor or lecturer has the opportunity to respond in kind, with text, sound and movie files-whichever may be the most appropriate form of feedback for the student. The tutor may also assign grades, and save her or his responses for further use as standard or user comments. While this software operates on a Unix system and is still in the development phase, it shows the potential for lecturers and teachers to provide appropriate feedback to students in a wide variety of formats. The authors suggest that *xmark* has the potential to assist university staff faced with increasing class sizes and time constraints to provide more effective comments and feedback to students.

The use of the internet is also providing a mechanism to deliver appropriate and 'in-time' feedback to students for IMM being developed for, and used on the World Wide Web. Freeman (1996) has used the model of a managed internet bulletin board in order to provide feedback for a very large group of business finance students. A statistical evaluation of the use of this mechanism indicated that students who rated the Frequently Asked Questions (FAQs) on the bulletin board as the most useful resource, actually performed better in their assigned case studies. The students also indicated that the speed at which their questions were answered using this system was very important for their overall understanding of the content matter. The examples illustrate the range of approaches modern software tools offer IMM designers to provide appropriate feedback for students using software.

3.5. Appropriate workload

3.5.1. Focusing on key concepts, and students' alternative frameworks, rather than on just covering the ground

An expository model of IMM, by its nature, focuses on covering the ground. A pre-emptive model, however, will endeavour to include alternative frameworks commonly held by students, by offering alternative pathways through the software, but still fails to address the time taken by individual students to work through the software. A transformative model involves discussion between the teacher and the student, or interaction between the software and the student, to determine the appropriate workload to satisfy the academic requirement of the course. This implies radical changes to curricula with consequent impacts on timetables, teaching spaces, and relationships between subjects. Both staff and students need to culturally adjust to new patterns of teaching in higher education (Wills & McNaught, 1996) and this adjustment needs to be recognised in IMM evaluation.

Conclusions

In this paper we have developed a framework which links pedagogical perspectives on teaching and learning to strategies for designing specific interactive multimedia elements related to particular desired educational outcomes.

This may assist in the development of software designs which are truly transformative—thus enabling students who use such software to change their own knowledge constructions at a fundamental level.

The framework may also facilitate understanding of the personal educational paradigm a IMM designer has. Many IMM developers adopt what they describe as a "pragmatic approach—if it works, use it". However, there is always a framework which guides decision making. Table 1 is intended to link explicit design strategies (IMM elements) to theoretical models (expository, pre-emptive or transformative) and make designers more reflective of their own practice.

For many IMM developers, designing IMM has been a subversive process—in that it challenged and changed many of their preconceived beliefs about teaching and learning. This process emerged only after a great deal of the project had been completed. A more conscious period of reflection about the conceptions of teaching and learning an IMM designer brings to a project may well broaden the design phase—leading to the incorporation of more student-centred IMM elements which engage students more actively in the learning process.

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