STRUCTURED OPEN-ENDED LEARNING ACTIVITIES USING CLIENT-SIDE INTERACTIVE OBJECTS

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ABSTRACT

Engaging students in meaningful learning activities that complement and enhance face to face and other traditional modes of teaching presents a major challenge to universities. Course delivery systems may incorporate generic mechanisms for assessment and basic feedback, but are limited in terms of richness of expression. The use of more open-ended exercises requiring teaching staff to correct and comment upon submitted work is under pressure with changing economic circumstances and student/ staff ratios. Attempts to create more sophisticated feedback interaction systems generally increase complexity in software and pedagogical design. This paper describes an approach that goes some way to enhance the student-tutor dialogue in on-line activities, while avoiding elaborate technical constructions and costly involvement of teaching staff. It uses the 'Learning Engine' model for on-line activities implemented by way of interactive objects embedded in a browser Web page. A scripted sequence of questions, assessment criteria and feedback is provided through a tutorial 'Itemset' object that can be extended by small 'interface' objects customised to meet different subject requirements. While the learning interface is important, more can be done to craft activity sequences that will promote learning. We incorporate self-assessment and reflective activities as useful learning strategies that also provide valuable information to the lecturer, for example by registering student degree of confidence in a submitted answer. Assessment of an answer may involve the consideration of multiple factors, with no single, correct interpretation. We can also turn part of the responsibility for learning back to the student by asking them to reflect on their initial effort in the light of 'expert' answers presented later and ranking themselves according to criteria devised by the lecturer. This approach to dealing with more complex content material has evolved from the real teaching needs in a variety of disciplines including Economics and Physiology. The paper will illustrate a number of pilot studies and suggest a conceptual framework for exploring the development of meaningful on-line learning activities. A pool of 'templates' for particular activity styles emerging from these projects will provide a means of scaling such techniques into more widespread use.

KEY WORDS

Open-ended, constructed-response, questions, on-line, assessment, interactivity, object-oriented.

1. INTRODUCTION

As we enter a new era of educational technology centred on the Internet, the challenge is to engage students in meaningful learning activities that complement and enhance face to face and other traditional modes of teaching. While Web-based course delivery systems may incorporate generic mechanisms for assessment and basic feedback, they are currently limited in richness of feedback and expression. Computer mediated communication techniques do offer opportunities for constructive learning environments but seem applicable only in limited situations. Learning activities of a more open-ended nature require an expression of depth of understanding, whether written, verbal or by some sort of symbolic construction appropriate to the subject. Specification of precise answers to which a computer mediated learning system can respond may not be possible. There are likely to be multiple criteria against which any response is to be considered. In addition, the nature of the activity will greatly influence the student's involvement with the learning task. It is far more significant for a student to independently construct relevant factors from a given scenario than to check them off a list presented in a traditional Multiple Choice Question (MCQ). Such open-ended learning experiences have traditionally relied on face to face tuition or required teaching staff to correct and comment on submitted work. Assessment instruments that are based on open-ended questions are increasingly under pressure as institutions grapple with economic pressures and changing student/staff ratios. Maximising the efficiency of these teaching resources and simultaneously creating open-ended responsive learning activities is where on-line systems demonstrate great potential. However, more sophisticated open-ended interaction systems will generally increase complexity in software and pedagogical design.

1.1 BRINGING IN RESPONSIVE OPEN-ENDED LEARNING ACTIVITY

We are interested in finding a way to enhance the student-lecturer dialogue in on-line activities of an open-ended question type. To do so we need to work in an area often beyond the scope of pre-defined technical software solutions such as broad-scale course delivery systems. It is important to maintain a focus on a pedagogical perspective involving the lecturers' knowledge of good teaching and learning, what their students bring to the learning experience and what is to be learned. We need to critically question the purpose of a proposed learning intervention. Would a set of printed notes be better than a Web-based version? What does the lecturer really want the students to be able to do? How will the lecturer know that they can do it? What learning strategies do students apply in different situations? Are these appropriate to the learning aim?

The direction we take in this paper has evolved out of the real teaching needs in a variety of disciplines and with different learning requirements. The paper examines how particular learning activities have been developed to suit departmental requirements in a number of discipline areas. While these departments have employed a particular software model to accomplish these aims, it is important to appreciate that the process of curriculum design has influenced the application of the model.

In this paper we start with a description of the model used from which a number of learning activities of an open-ended nature have been developed. We extend this to incorporate self-assessment and reflective activities as useful learning strategies. These also provide valuable information to the lecturer, for example by registering student confidence in a submitted answer. Assessment of an answer may involve the consideration of multiple factors, with no unique interpretation. Rather than relying on problematic software algorithms, we can turn the responsibility back to the student to reflect on their initial effort in relation to 'expert' answers presented, ranking themselves according to criteria devised by the lecturer. Finally, flowing out of these experiences, a pedagogical structure for thinking about development of such learning activities is suggested. This represents a bridge between the designers' understanding of coalface educational requirements, the software system and a scalable diffusion of the techniques into other departments.

1.2 THE LEARNING ENGINES INTERACTIVE OBJECT MODEL

The 'Learning Engine' (LE) functional object model has been used to produce classes of open-ended activities running as interactive objects embedded in the browser Web page as described in Fritze & Ip, (1998). These have been developed in Shockwave for Director. A tutorial 'Itemset' object has been used to implement sequences of questions, qualified by assessment criteria and feedback. These sequences of questions are thought of as a single learning 'activity', taking perhaps five minutes and involving perhaps 5-10 'tasks' with a variety of interaction styles. The particular working instance of the 'activity' is scripted by way of an XML document. XML is an important document structure definition recently ratified by the World Wide Web Consortium (W3C). For a general introduction to XML, refer to a recent feature in Byte Magazine by Mace et al, (1998).

In the LE model, 'interface' objects are used to extend the learning interface for different subject requirements and interaction styles. For example, in Kennedy & Fritze (1997), a free form graphing object can provide a mechanism by which students are able to sketch basic graph forms to express their understanding of various quantitative relationships. Other interfaces have been developed to facilitate such operations as sorting and ordering text, construction or organisation of images and classification of images and text. In addition the model provides a software framework to which further customised interfaces can be added, for example an image that can be 'prodded' for hardness for use in Veterinary Science. While interface objects improve the naturalness of the interface, more can be done to craft activity sequences supporting particular strategies for learning. Our aim is to define various styles of activities that suit particular departmental requirements. Once defined, these become available resources in the armory of computer-based and traditional tools available across the institution.

1.3 THE PROCESS OF DEVELOPING OPEN-ENDED ACTIVITIES

Teaching, research and administration compete for a limited amount of academic time and inevitably the time taken to develop appropriate activities and to implement the teaching/ learning innovation is of increasing importance. In this project the work may be divided into three broad areas.

- The time spent thinking about and developing the particular style of activity. Experience suggests that it is difficult to pose questions that require students to explore their knowledge and understanding at a deep level and stimulate higher order thinking skills as identified in Bloom et al (1956) taxonomy. These questions require a greater investment in time. Similarly, designing the structure of the question such that it readily exposes misconceptions also requires much thought. Essentially however, as the focus of this project is to design a student learning and student/lecturer feedback tool and not an instrument of formal assessment that needs to be changed each year, the time costs involved, while substantive, are not ongoing. Once the lecturer has become familiar with the style of the question and an appropriate set is established the running costs in terms of time should be relatively small.
- The time needed to devise new questions as student needs alter and as the subject is adjusted following evaluation of the original set of activities. This is an on-going commitment by faculty staff. However it is not likely to be an addition to current good practice.
- The process of entering new content data into the working product is also an element of on-going work for faculty. The object/shell into which the content material is placed is designed to make this part of the process efficient and time effective. The loading of the material may be accomplished relatively easily by the lecturer or administrative staff and is ultimately to be a minor part of the whole process.

The learning curve for academic staff is not a steep one as the materials they develop can be easily placed in the object/shell. However the development of the content in the style of the question type is likely to be time consuming in the short run to the point where the lecturer becomes familiar with the format. Running, adjustment and on-going time costs are likely to be low.

2. EXAMPLES OF OPEN-ENDED ACTIVITIES

2.1 CRITICAL INFORMATION ANALYSIS IN ECONOMICS

The particular example outlined here is one component of a program to provide earlier and more extensive feedback to students and academic staff in relation to common areas of misconception or difficulty experienced by students in first year Introductory Macroeconomics. Earlier feedback to lecturers and students will allow for more informed decisions to be made in relation to subject development and study habits respectively. A computer assisted instruction module of open-ended text editing questions is designed to provide interactive, detailed and early feedback to students that is low cost in terms of time and money. The open-ended text editing question demands reflection on learning and allows a higher order of knowledge and understanding to be assessed than is commonly the case with multiple choice questions. The on-line activity is built out of a LE Itemset object and a text object in which the question is initially displayed (Figure 1). The Itemset script later reconfigures this object so that students can sort the elements of the question as well as enter additional text. A sample of the dialogue that may occur between the computer (C) and a student (S) working through task sequence is summarised in Table 1.

In this "critical information analysis" activity, students are initially presented with a question (Figure 1). They are not required to actually provide the answer the question. Instead, they are asked to consider whether there is sufficient, insufficient and/or redundant information provided by the question. This initial task, although posed in simple MCQ form, represents a statement of their understanding of the elements of information and associated theoretical concepts. To reinforce this commitment, they are required to enter their degree of confidence in their response at the point of submission (Figure 1). This encourages students to reflect on their understanding and provides the lecturer with more detailed information in relation to areas of the subject with which students are having difficulty. The student's responses are electronically tracked and reviewed. This provides the lecturer with information on student misconceptions that can be addressed in lectures within the same semester or provide the basis for curriculum adjustment in subsequent semesters.

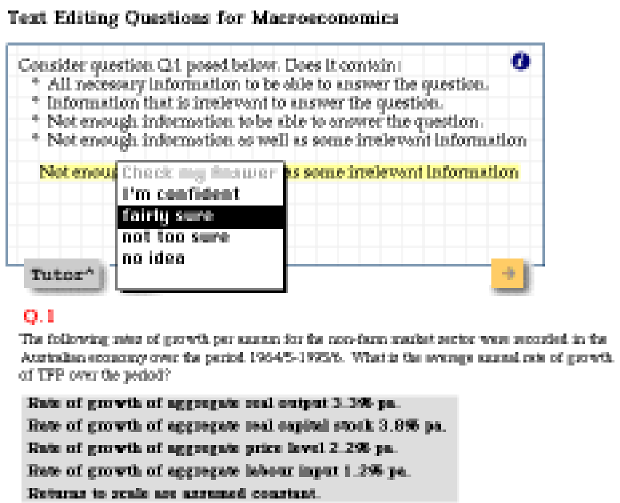

Figure 1: Task 1 of critical information analysis activity, registering degree of confidence

In the next stage of the activity, section 2, students are asked to identify any redundant information by dragging it out of the question to another area. They then type in any additional information they think may be needed to answer the question (Figure 2). Students are then provided with a response to the first part of the activity in section 3. In this case, one element of information is missing and an incorrect element is chosen. A further detailed explanation of what has been omitted and why this information is essential to answering the question is available at this point. In section 4 students complete a reflective self-assessment of their text response by comparing it to an expert answer provided in the module. This self-assessment is relayed to the lecturer. An email link to a tutor is provided to address any remaining problems students may have in relation to the set of text editing questions in the module.

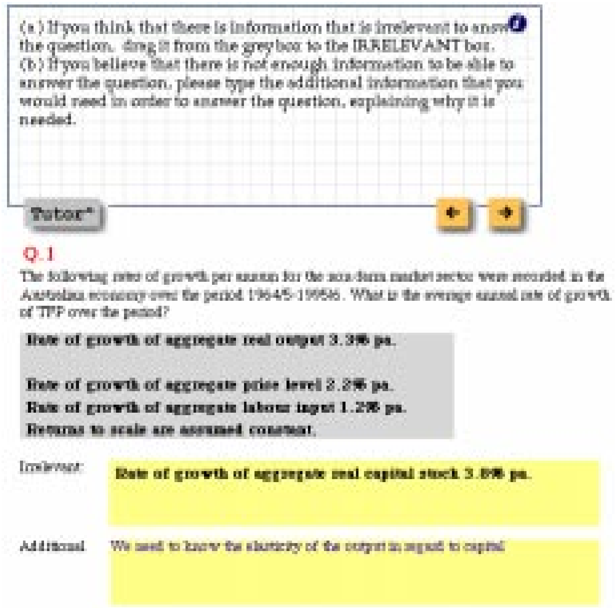

Figure 2: Critical analysis activity, identifying redundant and entering additional information

Table 1

Critical Information Analysis Dialogue in Microeconomics

		Dialogue between Computer (C) and student (S)	Comment
1.	C	*Consider the question below. Does it contain:* * *All necessary information to be able to answer the question.* * *Information that is irrelevant to answer the question.* * *Not enough information to be able to answer the question.* * *Not enough information as well as irrelevant information* *Question: The following rates of growth per annum for the non-farm market sector were recorded in the Australian economy over the period 1964/5-1995/6. What is the average annual rate of growth of TFP over the period?* *Rate of growth of aggregate real output 3.3% pa.* *Rate of growth of aggregate real capital stock 3.8% pa.* *Rate of growth of aggregate price level 2.2% pa.* *Rate of growth of aggregate labour input 1.2% pa.* *Returns to scale are assumed constant.*	Proposed question requiring student to analyse each piece of information and relate to the economic principles.
	S:	"Not enough information as well as some irrelevant" [SUBMIT selecting degree of confidence 'fairly sure']	Response is submitted. Degree of confidence registered.
2.	C	*(a) If you think there is information irrelevant to the question, drag it from the grey box to the IRRELEVANT box.* *(b) Type any additional information you think is necessary*	2 entry boxes appear for 'Irrelevant' and 'Additional' information
	S:	Drags 'aggregate real capital stock' into the 'Irrelevant' box. Types 'We need to know the elasticity of the output in regard to capital' in the 'Additional' box. [SUBMIT] [NEXT]	MCQ-style selection of irrelevant information. Open-ended text entry is submitted.
3.	C	*OK, check your answer starting with the information you thought irrelevant to the question.*	
	S:	[CHECK]	
3.b	C	*EXPLANATION: To estimate TFP growth, if we already know the growth of output and inputs in real terms, we do not need to know what is happening to the price level. The price level information is irrelevant. The rate of growth of aggregate real capital stock is required because...*	Incorrect! 2 criteria fail and return relevant feedback.
	S:	Organises the correct redundant information [CHECK] [NEXT]	Redundant information now identified.
4.	C	*Now you should check any additional information you thought necessary. Examine the expert explanation below. Compare this with what you entered, then rate your own response as:* * *had no idea* * *partially correct* * *spot on* *EXPERT: "To calculate TFP growth we need to know the elasticity of output with respect to capital (or some way of establishing this) and we are not given this information."*	Expert answer provided. Student reflects on and assesses their answer.
	S:	S. selects 'partially correct'	Feedback to lecturer on open-ended text entry.

Variations on the style of activity would see students required to express the degree of confidence at different stages in the module. Section 4 could also be repeated with different criteria for self-assessment of the open-ended text response.

2.2 AN OPEN-ENDED ACTIVITY FOR PRELIMINARY INVESTIGATION OF ISSUES

From First Year, medical students in Physiology can be set a simple question on a health issue that they are able to explore using decision making processes that will later form part of their everyday medical practice. These questions deal with each of eight health issues related to individuals and the community, with a dual clinical and epidemiological focus. Such decision-making skills were previously developed in later years of the medical course when students had acquired factual knowledge. It was assumed that decision-making was learned implicitly in clinical contexts over many years. However, effective participation by students in the new medical curriculum requires them to develop these judgmental skills from the beginning of the course. This particular on-line activity is designed to fulfil part of that educational need within decision making modules (DMMs) integrated into the undergraduate medical curriculum. The DMMs will be scheduled in small group teaching sessions, as they are designed for cooperative learning.

The particular activity here is a precursor to more detailed research into particular issues. It will work in conjunction with similar activities posing other questions, for example “What is the association between risk of Cardiovascular Disease (CVD) and Blood Pressure (BP)?” or “What would be the magnitude of the decrease of BP that is needed to significantly reduce risk?” The purpose here is to stimulate initial thinking, to establish a baseline for students’ understanding and to have students recognise the importance of integrating knowledge from different areas of the curriculum and clinical issues.

At the end of a series of activities and associated data gathering, students are asked to formulate a principle that they submit electronically and further re-assess themselves against expert views. On the basis of their chosen principles, students will be asked to predict the significance of the health problem for the population (eg. in terms of risk of CVD in the 21st century), and ways of dealing with risk factors (eg. stress, smoking). The program will direct students to evidence used by experts in making such predictions.

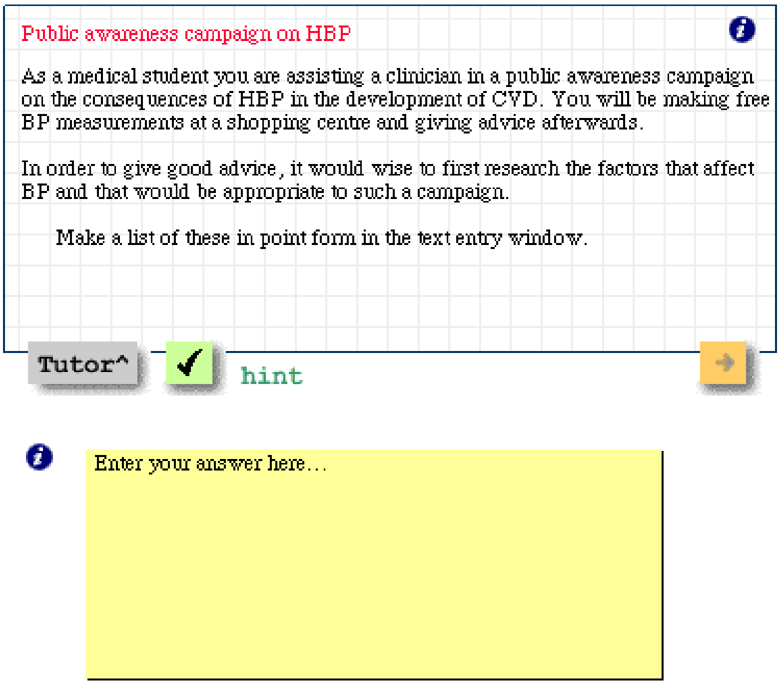

Figure 3: Open-ended issues activity with LE Itemset (top) and text-entry object (bottom)

Table 2

Open-Ended Major/Minor Issues Dialogue (Simplified)

		Dialogue between Computer (C) and student (S)	Comment
1.	C:	*As a medical student you are assisting a clinician in a public awareness campaign on the consequences of high BP in the development of CVD. You will be making free BP measurements at a shopping centre and giving advice afterwards. In order to give good advice, it would wise to first research the factors that affect BP and that would be appropriate to such a campaign. Make a list of these in point form in the text entry window.*	Open-ended research question eliciting student's initial 'research' proposal
	S:	"Diet – fats and sugars etc. Lack of activity/exercise Being over-weight" [SUBMIT]	Initial statement of understanding submitted
2.	C:	*Eh, hem. We would have expected at least 4 lines of factors.*	An initial compulsory criterion is failed
	S:	(adds) "....Being over stressed" [SUBMIT]	
2.b	C:	*We are surprised that you have not mentioned one particular major lifestyle factor that has a serious impact on a number of health areas. You had better do some more research into this...*	A second level criterion check for a major key word failed
	S:	(adds) "...smoking" [RESUBMIT]	
3.	C:	*Here are some MAJOR factors affecting the incidence of HBP that you certainly should be considering in this campaign. We will cover some others further on. Highlight those factors you identified...* *Smoking Exercise Drug intervention Diet Obesity Alcohol*	Multiple choice question will provide feedback to lecturers. Students may have to interpret in terms of their own wording.
	S:	Selects Smoking, Exercise, Obesity, Diet [SUBMIT] Examines further explanations on some factors by clicking on them [NEXT]	S. reflects back on submission, integrates new information
4.	C:	*There are of course other factors that you might have mentioned such as: cholesterol level, stress, nature of employment* *Click which ones you also referred to in you answer*	A second level of factors
	S:	Selects "Stress" [SUBMIT] Examines further explanations on some factors by clicking on them [NEXT]	Self-assessmentof second level factors
5.	C:	*In the light of this information, you should edit and re-submit your answer representing the issues you will need to spend time further researching.* *You may consider that some additional factors have not been raised here. You are welcome to enter these in the space provided below with your reasoning. Your lecturer will consider them.*	A integration of previous & new knowledge. Opportunity for debate
	S:	Redrafts list in the light of new information [SUBMIT selecting degree of confidence 'fairly sure']	Final draft submitted with expression of confidencelevel

The initial activity is constructed from an Itemset object working with a second interface object configured as a simple entry field (Figure 3). Its dialogue sequence (Table 3) consists of an initial open-ended statement that is then reflected upon in later stages. An initial compulsory criterion is used in section 2 to check that at least some attempt has been made. Once this has been met, criteria testing for fundamental key words are applied. The next two sections see expert responses to the question put forward for consideration and self-assessment by the student. The last section provides an opportunity for the student to resubmit their original research proposal in the light of reflection and new information. They are asked to register their confidence in this submission and also given the opportunity to register a disagreement with the expert answers put forward.

2.3 OTHER OPEN-ENDED ACTIVITY EXAMPLES

2.3.1 The Student as Critic

In a project for the Department of History, basic bibliographic research skills are to be tested. An open-ended activity has been devised in which students are presented with an example of a research essay bibliography that might have been submitted by another student. This may or may not contain omissions, errors in format or inappropriate citations that are to be identified in a 'tutor's report' written by the student. Once their initial report is submitted, the student is taken through a series of tasks in which they are asked whether or not they have considered particular assessment criteria. In some tasks, they must identify where specific problems are located by clicking in the bibliography. The underlying objective is to develop in the student a critical eye for preparing their own research bibliography, to understand the various requirements, search techniques and formatting standards.

2.3.2 Open-ended Graph Plotting Activities

Open-ended environments using a LE graphing interface have been described elsewhere (Kennedy & Fritze, 97). In a similar manner to the above text-entry activities, the graphing interface provides a task environment in which plots can be created in an unprompted manner – on 'blank graph paper', and to which multiple criteria can be applied in shaping feedback. Expert representations of the possible forms of a correct response can also be given either by scripted graph plots directed to the graphing object or by displaying images of real-life plots.

2.3.3 Image Construction

In the Department of Media Studies, activity styles are being created around the tutorial Itemset and an image constructor interface. Students can write descriptive narratives about presented images which can be deconstructed in a series of tasks reflecting on various aspects of the interpretation as identified by the lecturer. Students can also generate images that represent given themes by assembling image pieces from a palette. In both cases the use of expert interpretations and the reflection on initial submissions provide a powerful way in which to exercise the students' understanding in an expressive and responsive environment.

3. DISCUSSION

In the above examples, two perspectives guide thinking about and production of computer-assisted learning materials. The view of knowledge concerned with teaching/student requirements is ultimately the realm of the academic, but balanced against this is an understanding of possible technical solutions. In the above examples, the Learning Engines software model has been used although there are many other approaches that could be taken. Over reliance on any such technical model offering ready-made solutions jeopardises the educational focus. On the other hand, lack of understanding of the technical implementation and its implications can result in materials that do not fully realise the potential of the technology.

Table 3

Pedagogical elements for responsive learning activities

Pedagogical element	Teaching & Learning Description	LE Functional Implementation
1. Activity	A organised sequence of tasks taking perhaps 5 – 10 minutes. A dialogue between computer and student.	Tutorial Itemset running within a Web page, controlled by a single XML script.
2. Task	Student action to be taken or question to be answered. A task will usually have one or more criteria for assessment.	One of a sequence of Itemset question items. Student can move between tasks but access may be prevented until previous task completed.
Self-assessment	A special task in which the student reflects on and rates what they have done to date according to a given criterion and rating scale.	A MCQ of some type detailing some kind of rating scale.
Degree of confidence	Student asked to indicate how confident they feel about a task.	A MCQ detailing possible feelings.
Interface	The manner in which the student interacts with the discipline material within a task, by writing, organising or classifying information etc.	The MCQ, text entry, drag & drop or selection of hot text interface of the Itemset. Could be a customised software object such as a graph.
3. Criterion	How a task is evaluated. The result may trigger conditional feedback, sequence branching or assessment score.	Criteria can be attached to literally any object, typically a task and enacted when a particular message is sent to an object.
4. Feedback	Information is available as a result of student actions. Triggered by an assessment of criteria or a stage in task or activity.	Feedback can be by pop-up window or may be available with buttons. Typically triggered by a check of criteria.
Hint	A suggestion possibly based on a check of criteria.	Hint button.
Explanation	An explanation of how an answer is arrived at.	Explanation button, or once a task is completed, clicking on any answer.
Comment	Made in direct response to evaluation of a task, could be praise, warning or just information of interest.	On checking or submitting an answer a comment is assembled from the relevant criteria.
Show	A correct answer is inserted.	An menu option when all else fails.
5. Expert answer	This may be a detailed answer or value judgement of an expert. Could use this for reflection and self-assessment.	Could be implemented as reference as a pop-up window of text or HTML. Multiple expert opinions possible.

Bridging the divide between these perspectives is an important step in effective use of on-line technologies. In the immediate future we anticipate that broad scale course delivery systems will become the major force in the development of on-line learning courseware and indeed, in the way educators think about their teaching. In many ways this will be beneficial, but the need will remain to supplement these systems, for example to address the specific needs of particular content or discipline areas. An awareness of this situation is required, so that opportunities for more engaging learning environments are recognised.

3.1 A CONCEPTUAL MODEL FOR CONSTRUCTING RESPONSIVE LEARNING ACTIVITIES

Following from the experience of developing interactive components in the above projects, we venture to suggest here a conceptual framework that we have found useful for exploring pedagogical ideas and learning environments. This model is summarised in Table 3. It is intended here to provide a terminology for the elements with which responsive learning activities can be initially discussed and eventually implemented in a practical manner. It puts forward a language of real world teaching and learning rather than of technical structures, however it maintains a structural connection with a practical methodology for software implementation, the Learning Engines model. What is significant in this model is its object-based structure and close association with the elements and functions of learning, exemplified by the underlying XML description of content.

Although not detailed here, each of the pedagogical elements listed has an associated notation tag that can be organised into a descriptive XML document in concise format. Once an activity has been tested and found to be a useful style of interaction, the XML script document can be used to define a template through which similar instances of the activity can be regenerated. This technique is the subject of on-going work at the Multimedia Education Unit. Thus we believe that we have the foundations of a broad system for the production of responsive on-line activities that promote learning and the ability to teach effectively. Working from coalface departmental education needs and perceptions, we have a language with which ideas can be discussed and shaped and a method for scripting these ideas directly into operational form within the Web-based environment. Lastly, it is significant that these defined activities have the potential to be replicated across content areas by way of production templates.

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5. REFERENCES

Bloom, B.S., Engelhart, M.D., Furst, E.J. Hill, W.H. and Krathwohl, D.R. (1956). Taxonomy of educational Objectives: Cognitive domain, New York: McKay.

Fritze, P. & Ip, P. (1998). Learning Engines - a functional object model for developing learning resources for the Web. In T Ottman & I Tomek (Eds.), Proceedings of ED_MEDIA & ED-TELECOM 98 Conference. (pp. 342-7). Freiburg: Association for the Advancement of Computing in Education.

Kennedy, D. M., Fritze, P. & McTigue, P. (1997). An interactive graphing tool: The meeting of pedagogy and technology, In Proceedings of ASCILITE'97. Curtin University of Technology, Perth, 7-10 December.

Mace, S., Flohr, U., Dobson, R & Graham, T. 1998. BYTE Magazine - March 1998 / Cover Story. URL: http://www.byte.com/art/9803/sec5/art1.htm. CPM Media Inc. Accessed: 21.10.98