Special Issue on Theory for Learning Technologies: Editorial

Martin Oliver

The history of this issue can really be traced back to an annual internal conference of the Computers and Learning Research Group\(^1\) at the Open University. I had been invited to attend as a discussant, and as I listened to the papers, I was struck by the diversity of theories that people were drawing upon, and the very different ways in which they were using them. For some, a theory was a touchstone, a guiding set of principles, the foundation on which their work built. For others, theories were tools, and the important thing was having the right one for the job. What, I wondered, was the right way to use theory here? Should we believe in them, live them, and risk being dogmatic — or should we be pluralistic, tied to none, and risk being superficial?

These ideas were soon developed by discussions with colleagues preparing submissions for ALT-C 99\(^2\). The conference themes were policy, practice and partnership, with not a sign of foundational research work in sight — someone who shall remain nameless joked that theory had been replaced by alliteration. To remedy the situation, a workshop was proposed on the topic of theory and learning technology, and out of this grew what has now become the ALT\(^3\) Theory & Learning Technology Special Interest Group\(^4\).

From our meetings, it became clear that we wanted a rallying point, a forum in which to develop our ideas. The mailing list was all well and good, and the positional papers posted on the group’s site were all very stimulating, but a more intensive, sustained discussion was desired. It was at this point that we approached Simon Buckingham Shum for permission to run a special issue of JIME on the topic — and he kindly agreed, perhaps little realising the work that would be needed before it was finished.

\(^1\) http://iet.open.ac.uk/research/calrg/home.cfm
\(^2\) http://www.ilrt.bristol.ac.uk/alt-c99/
\(^3\) http://www.alt.ac.uk/
\(^4\) http://www.ucl.ac.uk/~uczamao/theory/

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The papers included in this issue are as varied and eclectic as the group that contributed them. Approaches vary considerably — from theory as tool, to theory as principle; from theory building, to theory using; from disciplines as diverse as film studies, psychology, sociology and education. So too do the topics — software tools, logic learning, metadata, multimedia; an array of mainstream issues, and other gems besides. To me, it is this diversity that makes this such an interesting area. It is constantly challenging; always impossible to tell quite what perspective might be brought to bear on your problem next. During the editing process, I received an irate email from one of the early readers of the pre-print material, complaining that no progress towards an overall theory for this area seemed to have been made. (I offered to let the questioner write such a piece, but they did not take me up on the offer.) This seems, to me, entirely appropriate. This is such a new landscape, so fast changing, that any attempt at this point to define it would surely be premature. Part of me suspects that attempts to define it will always be premature, and that what gives it its life, its vitality, is the mesmeric way in which it seems to shift and evolve, or the strange quality it has to seem utterly different when the same point is viewed from a new perspective. This, I think, is what these articles capture — the sense of change, challenge and above all exploration. I hope that you will enjoy reading and debating this collection as much as we writers and reviewers have.
Using Peer Teams to Lead Online Discussions

Liam Rourke and Terry Anderson

Abstract:

This study investigated an online course in which groups of four students were used to lead online discussions. The teams were examined for their ability to bring instructional design, discourse facilitation, and direct instruction to the discussions. The setting was a graduate-level communications networks course delivered asynchronously to a cohort group of 17 adults enrolled for professional development education. Interviews, questionnaires, and content analyses of the discussion transcripts indicate that the peer teams fulfilled each of the three roles and valued the experience. Students preferred the peer teams to the instructor as discussion leaders and reported that the discussions were helpful in achieving higher order learning objectives but could have been more challenging and critical.

Commentaries:

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1 Using Peer Teams to Lead Online Discussions

Computer conferencing has become a popular component of online learning. Asynchronous communication is one feature of these systems that researchers extol because of its ability to facilitate ‘anytime anywhere’ communication among peers and the instructor. Instructors, however, may not be as enthusiastic about this possibility. Hiltz (1988), for instance, has described teaching online as a bit like parenthood: “You are on duty all the time, and there seems to be no end to the demands on your time and energy” (p. 441). In Berge and Muilenburg’s (2000) survey of 1100 distance education instructors, a concern with increased time requirements was identified as the largest barrier to the adoption of networked forms of distance teaching. One possible solution to this problem was offered by Tagg (1994) who shared conference-moderating duties with his students. Not only did this alleviate demands on the instructor’s time, it produced unanticipated pedagogical benefits. Despite these encouraging results, few researchers have followed up on this approach. Those who have report contradictory results (Murphy, Cifuentes, Yakimovicz, Segur, Mahoney, and Kadali, 1996; Harrington & Hathaway, 1998). The purpose of this study was to explore the effectiveness of peer teams as online discussion leaders. Two questions guided the design of the investigation: Could the peer teams fulfill all the responsibilities of an effective online discussion leader? And, was the experience of being part of a discussion-leading team rewarding?

2 Literature Review

Computer conferencing is a web-based communication system that supports asynchronous, textual interaction between two or more persons. Messages are composed in the conferencing software and sent to a central location for retrieval from the World Wide Web (WWW). At this location, the messages are organized or ‘threaded’ to reflect some relevant feature of their overall structure, usually temporal, topical, or both.

One way to understand the educational purpose of these systems is to consider the root of the ‘conferencing’ metaphor, ‘confer:’ “To meet in order to deliberate together or compare views” (OED, 2000). In an educational context, this type of activity is conventionally referred to as ‘discussion’ (Bridges, 1979; Dillon, 1994; Gall & Gall, 1990; Hill, 1994; Wilen, 1990).

The pedagogical rationale for discussion is best understood from a constructivist perspective. Constructivists argue that knowledge is not so much discovered, or transmitted intact from one person to another, as it is created or ‘constructed’ by individuals attempting to bring meaning and coherence to new information and to integrate this knowledge with their prior experience. Discussion can be an excellent activity for supporting these efforts. Oliver and Naidu (1996) assert that explaining, elaborating, and defending one’s position to others (as well as to oneself)
forces learners to integrate and elaborate knowledge in ways that facilitate higher-order learning. Research in face-to-face settings by Arbes and Kitchener (1974), Azmata and Montgomery (1993), Berkowitz and Gibbs (1983), Gall and Gall (1990), Maitland and Goldman (1973) has provided empirical support for these notions.

The mode of communication afforded by computer conferencing prompted some authors to speculate that it would be an ideal medium to support substantive discussion. Asynchronous communication allows students to deliberate over others’ contributions and to articulate coherent and logical responses. The act of encoding ideas in textual format and communicating them to others forces cognitive processing and a resulting clarity that is strongly associated with scholarly practice and effective communication (Feenberg, 1989; Logan, 1995). There is some evidence to support these predictions (Beals, 1991; Hara, Bonk, & Angeli, 2000; Hillman, 1999; Newman, Webb, and Cochrane 1996; Zhu, 1996); however, the results are not entirely positive (Bullen, 1998; Kanuka & Anderson, 1998; Garrison, Anderson, and Archer, 2001; Harrington and Hathaway, 1998; McLoughlin, & Luca, 2000). McLaughlin and Luca’s (2000) lament summarizes the problems many instructors experience with the technology:

Analysis shows that most messages are in the category of comparing and sharing information. There is little evidence of the construction of new knowledge, critical analysis of peer ideas, or instances of negotiation. The discussions do not appear to foster testing and revision of ideas and negotiation of meaning which are processes fundamental to higher order thinking. Only a small percentage of contributions can be categorized as higher order cognition and awareness of knowledge building. (p. 5)

As many researchers have noted, the technology itself has less impact than the application or instructional design to which the communication tool is applied (Clark, 1983). Several authors have pointed out that certain qualities must be present if the technique is to be pedagogically effective (Garrison, Anderson, & Archer, in press; Kitchener and Arbes, 1974; Pomerantz, 1998). Kitchener and Arbes caution designers of the inadequacy of having students discuss course content without the benefit of a specific procedure or the guidance of a trained facilitator. Garrison et al. arrived at similar conclusions after observing online discussions that contained little evidence of higher levels of cognitive activity. Their diagnosis was that often the goals of lessons do not lend themselves to advanced inquiry, and there are deficiencies in guiding and shaping discourse toward higher cognitive activities.

Building on these observations, Anderson, Rourke, Garrison, and Archer (in press) have identified three roles or sets of responsibilities that must be addressed if online discussion is to be a valuable component of students’ learning. Referred to collectively as ‘teaching presence,’ the three roles are: instructional design and organization; discourse facilitation; and direct
instruction (see table 1). The first role includes responsibilities such as selecting topics from the course content that are suitable for discussion, implementing a specific discussion strategy, and establishing participation expectations. The second role, facilitating discourse, includes responsibilities such as drawing participants into the discussion; identifying areas of agreement and disagreement; and establishing a supportive climate for learning. The final role, direct instruction, includes responsibilities such as presenting content, diagnosing misconceptions, and providing assessment and feedback. Attending to each of these responsibilities is a complex and time-consuming task. Yet, each is necessary to ensure that the discussions contribute to the students’ learning experience.

In industrial models of distance education, or ‘big D. E.’ as Garrison and Anderson (1999) have called it, these responsibilities can be distributed among specialists--instructional designers, discussion moderators, subject matter experts. In "little D. E.,” on the other hand, and in on-campus education, they typically fall on the shoulders of a single instructor. In one of the few reports to present data on this subject, Harapniuk, Montgomerie, and Torgerson (1998) calculated that interacting with students in the computer conference component of a 13-week-course took an average of 7.5 hours per week. Thus, implementing an effective discussion is a time consuming task for instructors, who may not be able to fulfill all the responsibilities outlined by Anderson et al (in press).

Aside from this issue, researchers have identified other problems with the instructor exclusively taking the role of discussion leader. One consistently cited issue is the authoritarian presence that the instructor brings to the discussion. Beach (1968,1960), Bloxom, Caul, Fristoe, and Thomson (1975), Goldschmidt and Goldschmidt, (1976), Kremer and McGuiness (1988) each warn that this type of presence can inhibit the free exchange of ideas. As Kremer and McGuiness (1988) explain: “Where there is an obvious imbalance of power and expertise among those present, it is unlikely that an atmosphere conducive to openness, to debate, and to a free, frank, and fair exchange of opinion will ever be fostered” (p. 46). Ultimately, the concern is that instructor-led discussions can easily revert to the recitation structure, or initiate-respond-evaluate structure, of a traditional lecture in which the student is often a passive and unreflective audience member.

Coinciding with these disadvantages, are the advantages of using peers in the role of discussion leader. Aside from the obvious economic advantages reported by several authors (Bloxom et al., 1975; De Volder, Grave, & Gijselaers, 1985; Goldschmidt & Goldschmidt, 1976), there have been reports of affective and cognitive benefits. Beach (1974) provides a description of the environment in a peer-led discussion that is opposite to Kremer and McGuiness’ (1988) description of the instructor led discussion: “Student-led discussions provide a free and relaxed atmosphere for discussion, which makes students feel uninhibited in asking questions and
challenging the statements of others” (p. 192). This type of environment supports the beneficial processes associated with discussion and leads to positive evaluations from the students (Bluxom et al., Tagg, 1994; Kremer and McGuinness; Murphy et al., 1996). A final benefit is the increased depth of understanding that comes from leading the discussion. Bluxom et al. note “the person who leads the group can acquire an increased mastery of the subject matter by learning it well enough to deal with it effectively in the group discussion context” (p. 224).

Some authors suggest that these results accrue with little cost (De Volder, De Grave, & Giselaers, Murphy et al.; Rabe, 1973); however, not all are in agreement. The students that Schermerhorn, Golschmid, and Shore (1976) studied commented that they would “rather learn from the instructor than from peers because their peers do not know anymore than they do, and therefore might provide them with erroneous information” (p. 29). De Volder (1982) points out that discussion leaders who are subject matter experts function more effectively not only in the direct instruction role but also in the facilitating discourse role because they know when the discussion is going off-track; they can ask better questions; and they are better at stimulating discussion.

The research in the previous section was conducted primarily in face-to-face settings. One of the first researchers to experiment with the use of student moderators of online discussion was Tagg (1994). He evaluated a situation in which computer conferencing was used with a cohort group of graduate psychology students. Tagg reasoned that sharing moderating duties with students might ease the students’ apprehension about posting messages, transform the ‘unstructured melees’ into coherent discussions, and reverse the general opinion of his students that the conferences were not helping them to understand the course material. Tagg enlisted the services of two students selected from the class. One acted as a ‘topic leader’ whose role was to set the agenda for the discussions and offer some initial contributions. The other acted as a ‘topic reviewer’ whose function was to weave and summarize the discussions. He found that this improved the structure and coherence of the discussions, increased participation, and resulted in a much higher proportion of students reporting that the conference helped them understand the content.

Murphy et al. (1996) implemented a similar system in one of their computer conferences. The context was an undergraduate education course composed of students who had no previous experience with computer conferencing. Whereas Tagg (1994) had selected students from the class, Murphy et al. organized graduate students with some content expertise into teams of two to three to moderate. Aside from the objectives outlined by Tagg, the researchers also expected the graduate students to learn something about moderating online discussions. They report that the graduate students filled all of the roles required of moderators—organizational, social, intellectual, and technical—and did so in a manner that “was more effective than a single instructor would have been and far outweighed any negative aspects” (p. 34).
Harrington and Hathaway (1994) reasoned that peer facilitators would remove any power imbalances in the discussions, encourage freedom of expression, and give students the feeling that they owned the discussions. In their implementation, two or three students and a teaching assistant led the others through a discussion that focused on dilemmas familiar to practitioners in the field. The goals of the discussion were to identify and reflect on taken-for-granted-assumptions. Harrington and Hathaway’s results were not as positive as Tagg’s (1994) or Murphy et al.’s (1996). They found that unsupported opinions dominated the discussion, the homogeneity of group members prevented the production of the multiple perspectives, and taken-for-granted-assumptions were rarely questioned. It appears that some of the tasks that instructors would address naturally as discussion leaders were not addressed by the student moderators.

The theoretical rationale for using students to lead online discussions is sound, and the preliminary results sufficiently encouraging to warrant further study. The purpose of this study is to examine this strategy more thoroughly by evaluating the performance of the peer teams against a specific set of responsibilities that are required of effective discussion leaders. We compare the performance of peer teams to the performance of the instructor on their ability to satisfy the three teaching presence roles of instructional design and organisation; discourse facilitation; and direct instruction. The results will shed light on the contradictory results presented in the literature (Tagg, 1994; Murphy et al., 1996; Harrington and Hathaway, 1998) and further our understanding of how computer conferencing can be used in a manner that proves satisfying and valuable to both students and instructors.

3 Method

3.1 Case

The case we examined was the “Using and Managing Communications Networks” course offered through the University of Alberta’s Faculty of Extension as part of its Master of Arts in Communications and Technology program. The course was populated by a cohort group of 17 adult students, working full time while they completed their program. The cohort’s history included a three-week face-to-face session at the beginning of their program and one previous online course that included computer conferencing as part of the delivery.

In this 13-week course, the computer conference was used to support content-based discussion that corresponded to course readings and assignments. The instructor moderated the first five weeks of discussion to provide a model for the peer teams. Peer teams of four, configured randomly by the instructor, moderated the balance of the conference, which was divided into one-week sessions.
3.2 Data Collection and Analysis

Three methods of data collection and analysis were employed in this exploratory study including quantitative content analysis, closed-ended questionnaires, and semi structured interviews. Each is described in detail below.

3.3 Quantitative Content Analysis

One research technique that has been revived by computer-mediated-communication (CMC) researchers is the observational method known as content analysis. Berelson’s (1952) early definition of content analysis is one of the simplest and most direct— “a research technique for the objective, systematic, and quantitative description of the manifest content of communication” (p. 18). It is systematic in the sense that a theoretical, a priori set of categories is constructed into which communication content is classified. It is objective in the sense that classification is rule-based and the reliability of classification is tested by having multiple coders classify the same content. Its quantitative character is evident in the process of converting communication content into discrete units and calculating the frequency of occurrence of each unit.

This description projects a wholly positivist enterprise; however, subsequent authors have questioned each of the characteristics presented in Berelson’s (1952) definition, particularly when applied to different types of content. Potter and Levine-Donnerstein (1999) identify three types of content. With ‘manifest content,’ the features of communication that are salient for categorization reside on the surface of communication. This includes phenomena such as word counts or sex of participants. The classification of ‘latent pattern’ content relies on the identification of constellations of manifest content configured in particular ways. Potter offers the example of coding attire into two categories—formal and informal. Although the presence of a tie is objective and manifest, coders need more evidence (a suit perhaps) before they can make a decision, which ultimately contains elements of subjectivity. ‘Latent projective content’ is the most subjective of the three. Categorizing the presence of humour in transcripts, in our experience, is a thoroughly subjective enterprise that defies even the most elaborate rule system. The content in this study—the three roles of teaching presence—is considered to be latent pattern. For instance, to identify a message as containing ‘direct instruction’ requires a few instances or a crescendo of instances of “summarizing the discussion.”

The coding scheme that we used to categorize the discussion leaders’ messages was developed by Anderson et al. (in press) and is presented in table 1.
Table 1: Roles and responsibilities of teaching presence

<table>
<thead>
<tr>
<th>Roles</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional design and organization</td>
<td>Setting curriculum</td>
</tr>
<tr>
<td></td>
<td>Designing methods</td>
</tr>
<tr>
<td></td>
<td>Establishing time parameters</td>
</tr>
<tr>
<td></td>
<td>Utilizing medium effectively</td>
</tr>
<tr>
<td></td>
<td>Establishing 'netiquette'</td>
</tr>
<tr>
<td></td>
<td>Making macro-level comments about course content</td>
</tr>
<tr>
<td>Facilitating discourse</td>
<td>Identifying areas of agreement/disagreement</td>
</tr>
<tr>
<td></td>
<td>Seeking to reach consensus/understanding</td>
</tr>
<tr>
<td></td>
<td>Encouraging, acknowledging, or reinforcing student contributions</td>
</tr>
<tr>
<td></td>
<td>Setting climate for learning</td>
</tr>
<tr>
<td></td>
<td>Drawing in participants, prompting discussion</td>
</tr>
<tr>
<td></td>
<td>Assess the efficacy of the process</td>
</tr>
<tr>
<td>Direct instruction</td>
<td>Presenting content</td>
</tr>
<tr>
<td></td>
<td>Focusing the discussion on specific issues</td>
</tr>
<tr>
<td></td>
<td>Summarizing the discussion</td>
</tr>
<tr>
<td></td>
<td>Confirming understanding through assessment and explanatory feedback.</td>
</tr>
<tr>
<td></td>
<td>Diagnosing misconceptions</td>
</tr>
<tr>
<td></td>
<td>Injecting knowledge from diverse sources</td>
</tr>
</tbody>
</table>

The message was selected as the unit of analysis, i.e. the segments of transcript that would be categorized and represented numerically. Although we have experimented with other units for this type of analysis, we find the message to be the most practical while simultaneously providing sufficient context to make a decision. (For commentary on the use of the content analysis technique in computer mediated communication research see Rourke, Anderson, Garrison, and Archer, in press; for empirical application of the technique, see Anderson,
Rourke, Garrison, and Archer, in press; Garrison, Anderson, and Archer; 2001; Garrison, Anderson, Rourke, and Archer, 2000; Rourke, Anderson, Garrison, and Archer, 1999).

The quantitative content analysis yields data describing the number of messages contributed by the discussion leaders and the proportion of these messages that contained elements of teaching presence. Comparisons are made between the performance of the five peer teams and the instructor.

### 3.4 Questionnaires

A closed-ended questionnaire, presented weekly, was used to gather information about the students’ perceptions of how well the discussion leaders were performing the teaching presence roles. The questionnaires consisted of ten items that corresponded to the roles outlined in table 1. For instance, the students’ perceptions of a discussion leader’s ability to perform the direct instruction role, was investigated with items such as: This week’s discussion leader provided knowledge from diverse sources,” and “This week’s discussion leader focused the discussion of specific issues.” Each of the ten items was followed by a five-point Likert scale anchored at one end by the response “Strongly Agree” and at the other by “Strongly Disagree”. The questionnaire was presented online, and a message was placed in the conferences at the end of each weekly discussion encouraging the students to complete the questionnaire. This data was not presented anonymously; however, only the principal research was aware of the respondents’ identity. Students were exempt from filling out the questionnaire during the week that their team led discussion.

Because we used only one non-random case, the questionnaire data was analyzed using the logic of quantitative single-case designs. The entire class was regarded as the ‘case,’ and the change in their responses across weeks were observed and described. Of particular interest were the differences between the students’ responses during the weeks in which the instructor led discussions versus the weeks in which the peer teams led discussions.

### 3.5 Semi-structured Interviews

To probe more broadly, the questionnaires and content analysis were supplemented with semi-structured interviews. In the interviews, the students were asked to talk about their experience as part of a peer team of discussion leaders; to compare the peer teams to the instructor on their ability to fulfill the teaching presence roles; and to discuss whether or not the discussions had contributed to their learning.
4 Results

4.1 Content Analysis

Two of the thirteen weeks of discussion were used to train the coders. Training was concluded after interrater agreement reached .90 ($k^2 = .82$). Two weeks of instructor-led discussion and all five weeks of peer team-led discussion were analyzed by two coders for the purposes of the study.

The total number of messages contributed by the discussion leaders across the seven weeks was 219. For each message, coders were required to make three binary decisions: the message contains/does not contain instructional design and administration; discourse facilitation; direct instruction. Each message could contain all three elements, none of the elements, or combinations of some elements. For the 219 messages, 657 decisions were required of the coders. Interrater agreement for these decisions was .75 ($k = 50.98$). This figure is above the .70 cut-off point for interpretable and replicable research proposed by Riffe, Lacy, and Fico (1998).

The average number of messages posted by the instructor per week was 7.5; for the peer teams, this figure was 40. Table 2 shows the proportion of messages that addressed each of teaching presence roles.

Table 2: Proportion of messages that addressed the three teaching presence roles by instructor versus peer teams

<table>
<thead>
<tr>
<th>Teaching presence role</th>
<th>Instructor</th>
<th>Peer teams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional design</td>
<td>.11</td>
<td>.19</td>
</tr>
<tr>
<td>Facilitating discourse</td>
<td>.23</td>
<td>.61</td>
</tr>
<tr>
<td>Direct instruction</td>
<td>.67</td>
<td>.52</td>
</tr>
<tr>
<td>Omnibus$^1$ messages</td>
<td>.41</td>
<td>.26</td>
</tr>
<tr>
<td>Empty$^2$ messages</td>
<td>.00</td>
<td>.14</td>
</tr>
</tbody>
</table>

1. Messages that address all three teaching presence roles.
2. Messages that do not address any of the teaching presence roles.

$^1$ Cohen’s kappa $(k)$ is a chance-corrected measure of agreement between two or more raters. For further discussion see Capozzoli, McSweeny, and Sinha (1999), Cohen (1960), and Rourke et al. (in press).
4.2 Questionnaire

Ten of the seventeen students filled out the surveys during all seven weeks of data collection. Scores for the five weeks in which the peer teams led discussions were averaged as were the scores for the two weeks in which the instructor did so. Table 3 shows that the students rated the peer moderating teams slightly higher than the instructor on their ability to fulfill the three teaching presence roles.

Table 3: Student ratings of peer teams vs. instructor on fulfillment of teaching presence roles.

<table>
<thead>
<tr>
<th>Teaching presence role</th>
<th>Instructor</th>
<th>Peer teams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional design</td>
<td>4.05</td>
<td>3.24</td>
</tr>
<tr>
<td>Facilitating discourse</td>
<td>4.30</td>
<td>3.44</td>
</tr>
<tr>
<td>Direct instruction</td>
<td>4.10</td>
<td>3.56</td>
</tr>
</tbody>
</table>

4.3 Semi-structured Interviews

Seven students were selected to be interviewed; with the selection a balance of male and female students, who had participated actively in the weekly discussions, and who represented each of the discussion leading groups, was sought. The telephone interviews lasted approximately 30 minutes and were recorded and transcribed to facilitate analysis. Interview transcripts were coded by both authors into five themes: the contribution of the discussions to learning; positive and negative aspects of both the peer teams’ and the instructor ability to lead discussion; and reflections on the experience of being part of a peer team of discussion leaders. After the data from the interviews were analyzed, we presented our interpretations to the participants, hoping for some feedback or further insight. None of the participants responded.

The first issue addressed in the interviews was whether the discussion contributed to the learning process. Students were divided on this point. Those who responded positively valued the variety of viewpoints and personal experiences that were presented: “The online discussion helped me to learn because it provided much more breadth and diversity of opinion. Sharing experiences and providing analogies is what makes the discussion a valuable part of learning”. Another student continued on this theme: “Listening to somebody who can talk about the content as a practitioner, somebody who can talk about the content as a pissed-off person who had to pay too much money the last time they had to have a consultant
come in; those are valuable things”. It seems that the multiple perspectives revealed different elements and nuances of the content that individual students may have overlooked and made the abstract material more concrete.

It was not only the additional perspectives that contributed to the students’ learning, but also the contradictory perspectives. As one student explained: "I went through the readings and then I’d go to the online discussion and somebody would say something and then I’d have to go back and look at the reading again because I didn’t see it that way. This sharpened up what I’d learned, what I’d read”. Another student confirmed this opinion:

*It is in the process of defending my position that I really start to think: Why do I feel that way? Why do I think that way? And, two things can happen: Either I become even more convinced of my position, or I go: Maybe I haven’t thought this through as deeply as I could have or should have.” For me, that’s what’s valuable about the online discussions.*

Those who said that they did not learn from the discussions raised a complaint common in computer conferencing research, which is that the discussions are not sufficiently critical or challenging. One student summarized this view:

*The discussions helped me to learn only very superficially. A lot of our discussion was mutual stroking. I think as a group we were very gentle with one another. I think we could have been less kissy and more challenging. It was just so kissy it was actually kind of sickening. I think we would have gotten a lot more out of it if we had been more critical, in a constructive way.*

This student was looking to her peers for critical comment, which would prompt her to reflect and construct knowledge, but was unable to find it in discussion that was “too kissy,” or as Archer has referred to them—“pathologically polite” (personal communication, 2001).

When asked to describe exactly what they had learned from the online discussions, the students were careful to distinguish between lower-order and higher-order cognitive objectives. "The first part of the course," one student explained, "was very technical. I think the online discussion was probably useless in terms of helping me to learn. The only way to learn that kind of stuff is to memorize it”. On higher order objectives however, their opinion was quite different: "When you’re dealing with knowledge, with real learning, that’s about applying a concept; it’s about applying an idea to a situation. When that’s the case, the online discussion becomes very valuable”.

The second issue that arose in the interviews was a comparison between the peer teams and the instructor on their respective ability to fulfil the three teaching presence roles. A majority of
students expressed a preference for the peer teams, explaining that their discussions were more responsive, more interesting, and more structured. The fact that the peer teams were more responsive is supported by evidence from the content analysis, which shows that the teams posted on average 40 messages per week—approximately 5 or 6 per day—compared to the instructors’ seven (1 per day). Here, the salient term is probably “teams” rather than “peers,” with the instructor being outnumbered four-to-one.

The fact that the peer-led discussions were more interesting could possibly be explained by amount of preparation that occurred. One student recounted the process:

_We brainstormed a lot of options looking for more creative ways of leading the discussion. A few of the ideas we toyed with were to have fictitious characters, to use anonymous posting, and to use dramatic elements. Our thought was ‘what can we do that’s different to get people’s attention?’ We wanted to shake things up a bit and create a bit of interest._

This level of preparation was common among the peer teams each of whom expressed some competitiveness with the other groups and who were being assessed on their performance as discussion leaders.

Another responsibility at which the peer teams excelled was structuring the discussions. The following comparison was offered by one of the students:

_The peer teams tended to guide in an on-going way more than the instructor did. They posed very specific questions, and they continually came back into the conversation—to probe for other things, to stimulate discussion along a track that might have been opened up, to bring the discussion back on track, and to take the discussion to the next topic area._

As an explanation, one student said that inexperience caused the peer teams to adhere to the prescriptive suggestions for moderating provided by the instructor:

_I think the student-led discussions were more structured, and it might have been the case of not having as much experience doing it whereas someone who’s been doing it for a long time would be more comfortable to sit back and let the conversation develop naturally._

A common concern about asking peers to assume the instructor role is their lack of content knowledge. When prompted on this subject, the students were dismissive. They said that they were not looking to the online discussions for an authoritative presentation of content, but rather for an exchange of opinions and a sharing of experiences. Instead, the students focused on the positive qualities the peer teams brought to the discussion: “The peer teams lack of subject matter expertise didn’t bother me at all. Most of the teams supplied additional reference...
materials, and they asked specific questions, and provided prompt replies.” Another student added: “I don't miss having the instructor leading the discussion because sometimes they're too authoritative and that kind of thing can shut down discussion. The reading material can provide subject matter.”

The final issue that we asked the students to talk about was their experience as part of a peer team of discussion leaders. Their uniformly positive comments focused on two issues. First, they enjoyed the experience—both leading the discussion and the team work; and second, they learned from the experience—about leading online discussion and about the course content.

Unanimously, the experience was described as enjoyable. One student expressed it this way: “It took a lot of time but it was so enjoyable that the time factor was irrelevant, I don't think there was any negative aspects”. When asked whether they had learned anything about leading online discussions, the responses were consistently of this nature: “My skills at engaging people in electronic conversations have benefited from doing the online moderating. There's definitely a practical and valuable component to it”.

Several of the students also indicated that they learned the content better during the week that they led discussion. They explained that they felt a responsibility to lead an interesting discussion, and to do so they felt they had to thoroughly understand the material. To accomplish this they read and processed the assigned readings more thoroughly than usual, and they searched for supplementary material. One student provided the following description:

I certainly delved more deeply into the supplementary readings for my topic than I did the other topics. I learned something, certainly. I took ownership over others’ learning. I felt I had to bring a richness to it, expand on the content, and make it stimulating. This gave me a better understanding of the material. I think you can't help but learn the subject matter more when you're getting more involved in it. You're more actively engaged with the content than you would be otherwise in just reading through it and responding, but not leading the discussion.

There were also beneficial effects on the social processes of online learning. One of the students explained that this came mainly from working in a team:

*It was valuable getting to know people. You can never underestimate the importance of working with someone and getting to know them on a professional and personal basis. I got to known my group members very well, and I feel extremely comfortable with them, whereas before this experience I didn't really know [group member] [group member] but now if I see them we’ve got this instant bond 'cause we’ve had to, you know, struggle together. It’s formed a relationship between us, so I think that’s a real valuable part.*
5 Discussion

The purpose of this study was to examine the effectiveness of using peer teams to lead online discussions. The amorphous process of ‘leading online discussion’ was operationalized using Anderson et al.’s (in press) construct teaching presence, which requires discussion leaders to assume three roles: instructional design and administration; discourse facilitation; and direct instruction. The quantitative and qualitative data indicate that teams of four students, selected from the class, were able to fulfill each of the three roles to the extent that students preferred them to the instructor. Working in teams to lead discussion was an enjoyable experience for the students, and it contributed to their learning.

Consistent with Tagg’s (1994) findings, students in the current study reported that the discussions led by peers were more structured and at the same time, more fluid. Our students added that the peer teams were more responsive and more interesting. Our results are also consistent with those of Murphy et al. (1996) who found that students gained a better understanding of how to lead online discussion. The results are somewhat consistent with those reported by Harrington and Hathaway (1998) who questioned the value of student-led online discussions that produced little challenging or critical discussion among the students. This is a common finding in CMC research (Bullen, 1998; Kanuka and Anderson, 1997; Garrison, Anderson, and Archer, 2001; McLoughlin and Luca 2000). When the students that we interviewed described the processes that make online discussion a valuable contribution to their learning, they appeared to be invoking a form of social cognitive conflict theory (Clement and Nastasi, 1988; Piaget, 1977). The underlying assumption of this theory is that knowledge is motivated, organized, and communicated in the context of social interaction. Doise and Mugny (1984) argued that when individuals operate on each other’s reasoning, they become aware of contradictions between their logic and that of their partner. The struggle to resolve the contradictions propels them to new and higher levels of understanding. Research by Bearison (1982), Doise and Mugny, and Perret-Clairmont, Perret, & Bell (1989) supports the assertion that the conflict embedded in a social situation may be more significant in facilitating cognitive development than the conflict of individual centrations alone. As Perret-Clairmont et al. explain: “The more direct the conflict that takes place in a social interaction the more likely the interaction will trigger a cognitive restructuring (p. 45-46).

Two important issues qualify the students’ preference for the peer teams over the instructor. First, the content of the discussions the instructor led was focussed exclusively on the technical content of the course; whereas the content of the discussions that the peer teams led focused on the social implications of the content. The students informed us that some types of content do not lend themselves to an exchange of opinions or perspectives, and that comparing interpretations is not the most efficient method of achieving lower-level knowledge objectives. The
presentation of this type of content also restricted the instructor mainly to the teaching presence role of direct instruction.

Second, the instructor continued to participate in the discussions during the weeks in which the peer teams acted as leaders. Therefore, any of the teaching presence responsibilities that peer teams might have overlooked or struggled with, such as ‘diagnosing misconceptions’ or ‘making macro-level comments about the course content’ were still assumed by the instructor.

The overwhelmingly positive results also need to be qualified. It must be recognized that this setting provided a best-case scenario in which to achieve success with online discussion led by teams of peers. The characteristics of the group—a graduate-level, professional development cohort, most of whom worked in the field of communications—are ideal for discussion, teamwork, and peer teaching. Epistemic development models (e.g. King and Kitchener, 1994; Baxter-Magolda, 1992; Perry, 1970) suggest that graduate students are much more likely to view knowledge as contextual and socially-constructed than their undergraduate counterparts. This attitude can be essential if students are to view discussion with peers as a worthwhile component of learning. As professionals, these students also have experience working in teams, and bring some experience to the role of discussion leader, often acquired through chairing meetings or other similarly relevant experiences. Their concurrent employment in the communications field also endowed them with valuable experiences and perspectives to bring to the discussion, and these were received as such by the other students.

It is encouraging to see that the results are supportive of the content analysis scheme developed by Anderson et al. (in press). The peer teams had higher frequencies and proportions of teaching presence and they were rated higher on the questionnaires than the instructor. Students’ conceptions of what should happen and what is valuable behavior from discussion leaders, as reported in the interviews, is consistent with the underlying model of teaching presence.

The results from this study point to two important issues for practitioners to consider when including online discussion in their instructional design, and when using peer teams to lead these discussions. First, the students’ experiences with the discussion technique confirm what is axiomatic in the literature on this topic: discussions are useful in achieving higher-order, but not lower-order learning objectives. Efforts to use discussion to facilitate the latter is inefficient, particularly in the time consuming asynchronous, text-based format, and is often met with frustration and dissatisfaction.

Second, the students have provided some insight into how exactly the online discussions help them achieve higher-order objectives. The additional perspectives offered by others in the form of opinion, personal experience, and analogy add to their understanding of the content, and make it more concrete. Contradictory perspectives disturb their initial impressions of the
content and prompt them to process it more thoroughly. This later process, however, can only be precipitated by challenging and critical interaction. As Brown (1989) notes: “Change does not occur when pseudo-consensus, conciliation, or juxtaposed centrations are tolerated” (p. 409).

Finally, when asked why they preferred one discussion to another, the students identified three characteristics: responsive, interesting, and structured. In this case, these characteristics were more commonly associated with the peer teams than with the instructor. However, there is no reason to regard these qualities as either intrinsic to peer-led discussion, or extrinsic to instructor-led discussion. The advantage that the peer discussion leaders had was that they worked in teams of four; therefore, they possessed sufficient resources to fulfill all of the teaching presence responsibilities. The implementation described in this case, in which the instructor maintained a presence even during the weeks in which the peer teams moderated, may be the best method for alleviating the demands on the instructor while simultaneously providing all the elements required for valuable discussion.

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Towards a theoretical base for educational multimedia design

Tom Boyle

Abstract:

The aim of this paper is to contribute to the construction of a systematic theoretical base for educational multimedia design. The paper delineates different layers of explanation. It then argues for the interactional layer as the most appropriate for multimedia learning environment design. It proposes ‘context’ as the central construct at this layer. The relationships between multimedia contexts are explored, especially the concept of different levels of contexts corresponding to different educational demands. Further meta-theoretical clarification on the difference between procedural and declarative modes of explanation precedes the final section of the paper. This section explores how the internal structure, the morphology, of contexts might best be delineated for capture in a systematic knowledge base. The paper argues strongly that this type of theoretical clarification is required if we are to move towards a more systematic, ‘scientific’ base for the construction of educational multimedia systems.

Commentaries:

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Keywords:

Educational multimedia, design, theory.
1 Introduction

There has been a very rapid expansion of educational multimedia since the early 1990s. The driving factors have been the advent of widely available multimedia computers, the impact of hypertext and hypermedia, and the explosive growth of the World Wide Web. The rapid expansion in activity has led to an increasingly urgent need for the development of a sound theoretical base. Despite the influence of constructivism, and to a lesser extent traditional instructional systems design (ISD), there is no clear formal theory of educational multimedia design. The aim of this article is to provide a coherent contribution to the development of this theoretical structure.

There are a number of requirements that such a theory should satisfy. These include the following attributes. It should be:

- **Universalistic:** it should not be proposing a particular ideological position, however attractive this may seem. It should be able to assimilate valid knowledge generated from quite different research traditions (e.g. constructivism and ISD).

- **Expandable and Open.** This area is expanding rapidly. The conceptual base ought to be able to capture new developments in a form that relates them in a clear, structured way to the established body of theoretical knowledge.

- **Formalisable:** the framework should support increasing precision in the representation of concepts and their relationships

- **Useful:** the systematic representation of knowledge cannot be just about educational design, but ought to be also for educational design. It should provide a deep knowledge base to guide the design process.

There have been two primary candidates for generating this theoretical base: constructivism (e.g. Jonassen, Mayes and McAleese 1993; Perkins 1991; Grabinger and Dunlap 1995) and traditional instructional systems design (e.g. Gagné and Briggs 1979; Price 1991). It is not the intention in this paper to go into a detailed critique of these approaches (see Boyle 1997 for critical reviews). This discussion would provide a lengthy distraction from the primary aim of the paper: to develop a new framework for understanding educational multimedia based on a radical departure from certain basic epistemological assumptions underpinning both constructivism and ISD. After this new framework has been introduced the question of assimilating the
The contributions of these two traditions becomes viewed from a distinctly different and more productive perspective.

The main themes of this paper are expounded in a series of sections:

Section 2 deals with the important meta-theoretical issue of layers of explanation and the selection of the appropriate layer of explanation for designing IMLEs (Interactive Multimedia Learning Environments).

Section 3 proposes ‘context’ as the central explanatory construct at the appropriate layer of explanation.

Section 4 expands on the possible structural relationships between IMLEs.

Section 5 returns to the meta-theoretical issues - in this case whether knowledge of learning context design is best captured with procedural or declarative modes of knowledge representation.

Section 6 looks at how the morphology of contexts might be delineated in a way that supports formal descriptions.

2 Layers of Explanation

The aim of this section is to clarify the issue of ‘layers of explanation’, and to identify that layer that provides the most secure foundation for a theory of educational multimedia design. There is considerable fuzziness in the literature over which layer of explanation to employ in constructing theoretical understanding. This fuzziness obstructs the construction of a clear, formal theoretical framework to guide design.

After reviewing a range of psychological theories Anderson (1990) outline three major layers of explanation. These layers are:

- the physiological layer,
- the cognitive layer and
- the ‘rational’ layer

Since the reaction against behaviourism, explanations in the psychology of learning are most often couched at the second layer - the ‘cognitive’ layer. The explanation of why people behave as they do is sought in theories of underlying cognitive processes. Extrapolating research work from cognitive psychology to Learning Technology, however, involves considerable difficulty.
As Laurillard (1993) points out, it may be difficult to extrapolate theoretical constructs developed to meet the quite different needs of a separate original discipline. There is a further significant problem. Hammond points this out:

“One might hope that research on the fundamentals of learning would provide guidance for the instructional designer. However, it is also a fact of life that we know very little about the detailed mechanisms of learning ...(p. 53)”.

Hammond proceeds to argue that our poor understanding of underlying cognitive processes is relatively unimportant:

“.. the more we are concerned with the practical aspects of instructional design the less importance this ignorance becomes. What matters is that we have some understanding of the situations and conditions that promote effective learning even if we don’t really understand what is going on in the learner’s head. It is the engineering rather than the science of learning that is important” (p53).

If Hammond is correct, it ought to be possible to provide a productive strategic base for the ‘engineering’ of learning which is consistent with, but not tied to, the scientific study of learning processes. This provides a principled base for freeing the designer from becoming embroiled in what Bruner describes as the labyrinthine complexities of cognitive psychology (Bruner 1990). The key to achieving this is to differentiate between different layers of explanation. The central argument is that design insights are often best expressed at a different explanatory level from that of cognitive psychology.

Anderson’s third layer of explanation is the ‘rational’ layer. This layer of explanation focuses on the functional adaptation of the person to the environment. It might thus better be described as the interactional layer. Anderson argues that considerable explanatory power can be generated by explanations expressed at this level. Explanations can be expressed at this interactional layer given fairly minimal assumptions about the nature of the underlying cognitive processes. This expresses more formally the practical point made by Hammond. We know a lot about the conditions that promote effective learning even if we do not understand the precise cognitive underpinnings. The job of the designer of IMLEs is to create effective environments for learning. Insights expressed at this interactional layer should thus provide a more direct mapping onto the task of designing multimedia learning environments.

The interactional approach simplifies the relationship between learning theory and educational design. It argues that we often have good robust knowledge of the contextual factors which affect learning. We often know how to vary these to improve learning. The ‘problems’ created by this knowledge for cognitive psychology - what are the precise underlying processes - are not
the problems of the IMLE designer. The task of the designer is to incorporate these contextual factors appropriately in the design. It should be noted that the interactional layer is not inconsistent with the cognitive layer, any more than the cognitive layer is inconsistent with the physiological layer. There is no ban on insights from the physiological or cognitive layers. The approach simply states that explanations at the interactional layer are the simplest and most productive. It also states that all insights from the other layers will have to be translated into changes at the interactional layer if they are to be applied.

The simplicity and clarity of the transfer go beyond the provision of heuristics for changing situational factors. What also carries across is the method of validation of the knowledge. These principles were established in psychology because experimentally (i.e. in controlled situations) they were shown to improve learning. The IMLE designer continues that process by testing the design changes in the system against user behaviour. The designer can then optimise the particular learning situation by adapting the situational variable to achieve an improved effect. These processes are normally called formative or integrative evaluation (Draper, Brown, Henderson and McAteer 1996). There is thus a natural affinity between the technology of IMLE design and psychological insights expressed at the interactional layer.

The proposal is thus that the interactional layer provides the most secure and productive base to build a theory for IMLE design. This proposal leads directly to the question of elucidating the central explanatory constructs to be applied at this layer.

3 The central explanatory construct

The central explanatory concept proposed at the interactional layer is that of ‘context’. The importance of context is echoed in a number of disciplines: psychology (e.g. Donaldson 1978; Bruner 1990), ethnomethodology and situated action research (e.g. Suchman 1987), linguistics (e.g. Halliday 1975; Coulthard 1985) and to a lesser extent film theory (Hodges and Sasnett 1993). Halliday (1975) points out that context must be treated as more than a vague social backdrop to action. It is rather, ‘an abstract representation of the relevant environment’ (Halliday 1975, p.11). Context is a construction that makes selective, holistic sense of the environment of interaction. This construct then guides adaptive action in that environment, e.g. what type of learning actions to undertake. The central challenge for educational multimedia designers is to create contexts that promote effective learning.

Specific guidance on how to achieve this goal is given in several contributory disciplines to multimedia design, especially linguistics, situated action theory, film theory and psychology. The contributions from film theory, linguistics and psychology are developed in some detail in Boyle (1997). It is not the intention here to rehearse these arguments here in detail. However, a brief résumé of these arguments is provided to illustrate how they fit within the overarching theme of this paper.
Hodges and Sasnett (1993) point out that certain traditional concepts from film theory can be carried over into multimedia design by using context as the central organising concept. In film theory the tasks of creating and linking scenes are treated through the use of concepts such as mis-en-scene and montage. Mis-en-scene is concerned with the selection and framing of the content in a scene. Montage concerns the linking of these scenes to create a coherent overall artefact. A scene, however, is essentially a one-way mode of communication. Hodges and Sasnett (1993) argue that the transformation of the central explanatory concept from ‘scene’ to ‘context’ entails the incorporation of a major extra design concern: interactivity. They argue that the concept of ‘context’ can both capture concepts from traditional film theory and enhance this understanding through the addition of the concept of interactivity. From this perspective a context might be visualized as an interactive scene. As designers we engage learners in interactive scenarios. We impact on the learner through our skill in building these contexts.

The key point captured in the quote from Hammond given earlier is that the study of psychology has revealed considerably more about the contextual factors that influence learning than about the underlying cognitive processes involved. There is a central pivot where the primary concerns of psychology and learning technology both join and diverge. Psychologists attempt to create theories to explain the cognitive processes involved in learning (although the behaviourists eschewed this endeavour). However, the role of the learning technologist or educational multimedia designer is quite different. Their role is to construct contexts that promote effective learning. Context is the natural base concept for the learning technologist.

Two major challenges arise in the design of contexts:

1. the creation of the internal structure of the context;
2. the structuring of contexts in relationship to each other.

The second question will be discussed before discussing possible data-structures for capturing, in a declarative form, the design knowledge involved in constructing contexts for learning.

4 ‘Montage’: the structural relationships between learning contexts.

A context consists of the framing of content along with associated interactivity. Figure 1 provides an example from a system called DOVE (Boyle, Stevens-Wood, Zhu and Tikka 1996). The DOVE system provides a kind of virtual field trip in Biology. The topic is the observation and recording of animal behaviour. Figure 1 is a screen from the first learning block. The student observes the video and selects a description of the animal behaviour. The aim of this
early section is to help the student distinguish between anthropomorphic and non-anthropomorphic descriptions. In Figure 1 the learner has just made a choice, by clicking on the panel on the right of the screen, and received feedback. The DOVE system frames the main context and associated interactivity in a book-like form. The students engage in the activity on the screen and then page forwards/back, or in later pages jump to a video glossary section. Contexts, however, may have other contexts embedded within them. For example, the video of the animal behaviour along with the appropriate interactivity is presented with the familiar contextual frame of a VCR player. This sub-context has a clear functional role in the main context and the two operate harmoniously together.

Figures 2a and 2b provide another illustration of a significant ‘montage’ relationship between contexts. The screen dumps are from the DFML Web based system (Boyle and Payne 1999). This was developed to complement the book ‘Design for Multimedia Learning’ (Boyle 1997). Figure 2a is a screen from the site. The site was constructed to support very rapid navigation from a section in the book to the equivalent section on the Web site. The site does not attempt to duplicate the book. It gives access to multimedia resources that expand and illustrate the
abstract points made in the book. The panel on the left permits rapid drill down navigation to any section in the site (Figure 2a). The main panel on the right then displays the key points from that section in the book. Opposite the paragraph there may be a link to multimedia resources that illustrate/expand on the key point made in the paragraph. The main context thus provides controlled access to other contexts which have their own framing of content and interactivity. Figure 2 shows one of these contexts activated.

The DFML site is based on a very explicit ‘layering’ of contexts. The main site operates at the courseware level – it covers a substantial curriculum area for a module on interactive multimedia design. The ‘micro-contexts’ act at the next level down – ‘resources’. These learning contexts deal with specific themes or issues, e.g. using illusions to illustrate the active nature of perception. The interface between the two levels is kept very clean. It is managed through specific links kept on a separate part of the courseware context screens. This greatly aids portability and re-use, and ongoing development. The resource contexts can all be used independently from this particular courseware context.

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Figure 2 shows one of these contexts activated.
The courseware context in turn 'plugs in to' the (higher level) classware level context, as exemplified in a VLE such as WebCT. This permits the multimedia courseware context to be incorporated in a wider virtual classroom with organised discussion groups etc. The construction of learning contexts can thus be structured on a series of levels. If the interfaces between these levels are kept as simple as possible this greatly facilitates re-use and recombination.

In the first system (Figure 1) the layering is implicit. The 'VCR' context was authored to be embedded within the wider context; it was not designed to be used as a separate, independent context. The second system (Figures 2a and 2b), however, was designed explicitly on a series of levels. The interfaces between entities at different levels (e.g. courseware and resources) are kept as simple and clean as possible. This greatly facilitates the re-use of the resources in different contexts. It also supports the dynamic, ongoing development of the courseware through the addition of extra multimedia resources.

The manipulation of learning contexts goes beyond the provision of 'static' contexts for action. It may involve changes over time in the context to suit the evolving needs of the learner, e.g. the manipulation of scaffolding. Scaffolding involves the provision and gradual removal of extra contextual support for the learner. In scaffolding the designer first finds a level of contextual support which the learner can handle. This level of extra support in the context is then gradually removed to enable the learner to become a more independent problem solver (for examples see Jackson, Stratford, Kračík, and Soloway 1996; Linn 1996; Guzdial, Kolodner, Hmelo, Narayanan, Carlson, Rappin, Hubscher, Burns, and Newsletter 1996). It may be noted that the fact that the precise cognitive base for scaffolding is problematic is unimportant for the designer. It provides a powerful tool for the engineering of learning contexts. The goal of a design theory is to articulate, evaluate and capture in a communicable form these 'engineering' techniques.\(^2\)

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\(^2\) Editorial Note: The idea of layers, and of the relationship between them, was clarified and developed in a discussion between the author and the reviewers: http://www-jime.open.ac.uk/Reviews/get/boyle/7/3.html?embed=-1
Towards a theoretical base for educational multimedia design

Boyle

Figure 2b: Screen with a resource context loaded

5 Mode of explanation: declarative versus procedural

The next task in exploring 'context' is to delineate the internal structure of contexts in a more analytic and formal way. Before tackling this issue, however, it is useful to clarify the mode of explanation in which we should attempt to capture this knowledge.

How should knowledge of the design options in structuring learning contexts be captured? Strategic approaches as varied as constructivism and ISD have shared the implicit assumption that knowledge should be captured in the procedural mode i.e. as guidelines or instructions on how to do things. It seems natural to express knowledge in this way, given that the purpose is to construct effective learning environments. A 'scientific' approach to a subject aims to produce a body of knowledge that is increasingly comprehensive, systematic and precise. However, the more precise we make a procedural representation, the more prescriptive it becomes. Since there are many rival procedural approaches increasing prescription also leads to increasing fragmentation. A fragmented set of prescriptions does not provide a good theoretical base for design. It is noticeable that knowledge expressed in the constructivist tradition tends
to remain at a high level. Concepts like 'authentic contexts', 'rich interaction' and 'collaborative learning' provide powerful heuristics. But they do not provide precise guidance, nor can they be formalized to do so without undermining the spirit of the constructivist approach. The format of representing knowledge is self-limiting: it cannot become too precise for fear of undermining its central ethos.

What might be an appropriate alternative form for knowledge capture and representation? Many disciplines (for example, linguistics, computer science) make a distinction between procedural and declarative representations of knowledge. A declarative approach sets out not how to do something but what can be done. A grammar in linguistics, for example, describes the abstract structure underlying what can be produced in a language. The grammar does not specify what will be done. The creative activation of this knowledge base is at the disposal of the user/speaker. A theory in linguistics is thus quite different from a theory in physics. It provides both for systematic formal description while retaining creativity in the activation of that knowledge. The computer language Prolog in a similar way describes the structure of a knowledge base rather than specifying a set of instructions for action.³

This systematic, integrated declaration of knowledge turns out to have some very powerful features. A declarative knowledge base can be activated in many different ways. This might be best illustrated by a common form of declarative representation – a map. A map provides a systematic, integrated description of a particular geographic domain. This description, it should be noted, is both abstract and conventionalized. This knowledge base can be used to construct a route from any location on the map, through a series of ‘valid’ steps, to any other location on the map. This is far more powerful than any set of procedural descriptions. The language Prolog operates in the same way, although in this case the knowledge is captured in textual rather than graphic form.

The argument in this paper is that the systematic capture of knowledge for IMLE design is best based on a declarative approach. This has a number of advantages over a procedural approach:

• The declarative approach allows for a systematic, integrated representation of knowledge.

• Increasing levels of precision in this knowledge (e.g. as in a map) empower the creativity of the user rather than constrain it as in a procedural approach.

³ Significantly different positions on the topic of grammar were taken by a reviewer and the author. These are elaborated in exchanges in the accompanying discussion: http://www-jime.open.ac.uk/Reviews/get/boyle/10/1.html and http://www-jime.open.ac.uk/Reviews/get/boyle/10/2.html
A declarative approach can capture different approaches to design as alternative options for action. It does not reject knowledge because it comes from a rival ideological prescription for action; a declarative approach judges solely on whether a proposal provides a valid option for action. It then seeks to relate that to other options to clarify the choices available.

One of the criteria for a good theory is that it ought to be able to assimilate rather than dismiss its predecessors or rivals. The key point here is that the declarative approach does not negate procedural approaches. It aims to provide a descriptive, conceptual representation of the ‘action potential’ open to the designer. Procedural activation across this declarative landscape may be guided by specific procedural heuristics or guidelines. Creative designers may choose their own paths. The important point is that procedural and declarative representations of knowledge are not alternatives. They operate at different levels of abstraction. It is the deeper declarative level of abstraction that offers the potential for a systematic, unified theoretical base for the discipline.

In order for a declarative approach to succeed it requires an appropriate data structure which will capture the analysis and representation of knowledge in the domain. An important question is thus: what is the appropriate concept or construct for the capture and representation of knowledge of learning environment design? Given the space limitations of this article, and the focus in the paper on fundamentals, it is impossible to go into a detailed exposition. However, the paper will point to one research direction and to reading where a more detailed exposition of these ideas is given.

6 The morphology of contexts: towards the analysis and synthesis of contexts

The paper has already argued that ‘context’ should be the central explanatory construct. This provides a starting point. A major research task is then how to delineate and analyse the formal internal structure of contexts. This analytic knowledge, captured in an appropriate descriptive form, should provide a knowledge base for IMLE design.

One approach that would capture the key aspects of context in a formal way seems to be provided by context-based approaches in formal linguistics. Systemic Linguistics argues that language has evolved to provide communication in context, and the deep structure of language reflects this fundamental influence. It argues that there are three abstract macro-functions that underpin the production of all linguistic communication (Halliday 1973a, Halliday 1973b). These macro-functions provide the architectural base for the deep structure of grammar. Choices are made in parallel from the options available on these three macro-functions in the creation of all communicative utterances. These macro-functions concern:
• the construction of the content of the message - the coherent linking of agents, actions states and objects to convey a message (called the ideational function);

• the management of the interpersonal roles and relationships in the communication - whether the message is embedded in the form of a statement, question, order etc. (called the interpersonal function);

• the integration of all the other elements to create of a coherent overall communicative 'text', e.g. a coherent description stretching over several sentences (called the textual function).

Boyle (1997) argues that the creation of multimedia contexts involves the action of three corresponding macro-functions. In the construction of educational multimedia these involve:

• the **content structuring** macro-function: the selection and structuring of the learning content in the multimedia context;

• the **interactivity** macro-function: designing for user interaction with this content;

• the **compositional** macro-function: the creation of a coherent overall composition, both within and across contexts.

There are strong correspondences between the first two macro-functions and the traditional educational concerns of curriculum (the structuring of the content to be learned) and pedagogy (the structuring of learning interactions). The macro-functions thus synthesise contributions from a number of significant contributory disciplines. These contributions tend to complement one another, and provide a richer picture for the multimedia designer. The third macro-function has no marked parallel in educational theory, but the contributions from linguistics and film theory help to fill out this concept.

It is beyond the scope of this paper to discuss these issues in depth. A detailed discussion of the analysis of learning contexts using this approach, with several worked examples, is provided in Boyle (1997). However, it does point to a significant research challenge: how to capture in a systematic, unified knowledge base the sophisticated options in constructing educational multimedia contexts. Such knowledge might be attached to re-usable learning objects to mark the choices of content structuring, interaction and composition they embody. This would greatly enhance the educational use of learning objects which are at present pedagogically limited (Cowley and Wesson 2000, Hepburn and Place 2000). There are thus considerable practical as well as theoretical benefits from engaging in this task of the systematic capture of design choices and their relationships in the construction of IMLE contexts.
7 Summary

The paper is concerned with how to construct a systematic theoretical base for educational multimedia design. It has discussed two meta-theoretical issues (examination of the basis on which a theory may be built) and three main theoretical issues.

The meta-theoretical issues concern layer and mode of explanation –

• There are distinct layers at which a theoretical framework may be constructed. In particular there is a distinction between cognitive and interactional layers of explanation. The paper proposes that the interactional layer is the most appropriate for multimedia learning environment design.

• There is a clear and important distinction between procedural and declarative modes of knowledge representation. Explanatory knowledge may be expressed in either mode. However, the declarative mode provides a basis for knowledge representation that is more systematic, unified and precise.

The theoretical issues concern the central explanatory construct, and the internal structure and external structural relationships of this construct -

• Context is proposed as the central explanatory construct at the interactional layer.

• The paper pointed to the importance of finding data structures for capturing the basic abstract structure of contexts conceived as a trinity of macro-functions involving content structuring, interactivity and the composition.

• Multimedia learning environments may consist of several interrelated contexts. The concept of layering of contexts from ‘resources’ through courseware to classware is particularly important.

A basis proposition of the paper is that this type of theoretical clarification is necessary to support a move from conflicting prescriptions towards a more systematic, ‘scientific’ basis for computer-based multimedia learning environments.
8 References


Theoretical Models of the Role of Visualisation in Learning Formal Reasoning

Martin Oliver, James Aczel

Abstract:

Although there is empirical evidence that visualisation tools can help students to learn formal subjects such as logic, and although particular strategies and conceptual difficulties have been identified, it has so far proved difficult to provide a general model of learning in this context that accounts for these findings in a systematic way. In this paper, four attempts at explaining the relative difficulty of formal concepts and the role of visualisation in this learning process are presented. These explanations draw on several existing theories, including Vygotsky’s Zone of Proximal Development, Green’s Cognitive Dimensions, the Popper-Campbell model of conjectural learning, and cognitive complexity.

The paper concludes with a comparison of the utility and applicability of the different models. It is also accompanied by a reflexive commentary* (see footnotes) that examines the ways in which theory has been used within these arguments, and which attempts to relate these uses to the wider context of learning technology research.

Commentaries:

All JIME articles are published with links to a commentaries area, which includes part of the article’s original review debate. Readers are invited to make use of this resource, and to add their own commentaries. The authors, reviewers, and anyone else who has 'subscribed' to this article via the website will receive e-mail copies of your postings.

* See page 29: A commentary on the use of theory in the analysis of the Jape study

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1 Introduction

Studies of students studying logic have demonstrated that using visual representations can both speed and facilitate learning. However, although these studies have identified specific problems and difficulties encountered by students during this process, few have attempted to explain either these or the role of visualisation in terms of theories of learning.

In this paper, a series of theoretical models will be used to try and provide just such an account of the role of visualisation in logic learning. The analysis is based upon research into the ways in which students use the software tool Jape (Just Another Proof Editor; Bornat & Sufrin, 1996; available at http://users.comlab.ox.ac.uk/bernard.sufrin/jape.html). These analyses attempt to explain how the development of formal reasoning skills relates to the students’ learning of logical concepts, why certain logical rules are more complicated than others and how visualisation provides support for students as they learn these topics. The paper will conclude with a discussion of the strengths and limitations of each approach.

2 The development of strategies for formal reasoning

Formal reasoning is an abstract subject that many students find difficult and demotivating (Cheng et al., 1986). Moreover, it is a topic that may require years of instruction, and even then, may not support transfer, even to closely related domains (van der Pal, 1996). Research to date has helped to map out and to explain some of the key difficulties facing students learning formal reasoning. Fung & O’Shea (1994), for example, identified a number of problems facing learners, including a lack of familiarity with formal notation, an inability to break problems into manageable components, a lack of formula manipulation skills and an inability to extract general principles from specific cases. Oliver (1997) has carried out further research into a particular refinement of classical first-order logic called Modal logic. This work showed that negative propositions, double negatives, longer strings of operators and the use of abstract notation exacerbate students’ problems, and can result in students acquiring the skills needed to manipulate logical expressions without fully understanding them.

However, one criticism of these findings is that they concentrate on specific learning objectives or obstacles. They relate purely to demonstrable outcomes of learning, rather than explaining the process by which these concepts or abilities are acquired. As a way of overcoming these limitations, Aczel et al. (1999a) have begun to explore the processes whereby students acquire such logical concepts.

This research involved a series of studies with 170 computer science undergraduates taking an introductory course in propositional and predicate logic. The students were expected to translate

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See page 29: A commentary on the use of theory in the analysis of the Jape study

Journal of Interactive Media in Education, 2002 (3)
natural language statements into a given formal representation, to evaluate formal representations semantically, and to prove conjectures using formal rules. *jape* was provided to support the learning process. The software is a proof tool that allows students to manipulate proofs using a mouse; when users apply a rule to a line of the proof, the software calculates the consequences. *jape* can be configured to use a variety of logics, to present proofs in different ways and to allow various user actions. However, this research involved a particular implementation, called *Irl Jape*, which has been configured with the style of logic used on the course and pre-loaded with around 70 conjectures.

Three overlapping studies were conducted. In order to identify those features of the software that support learning, it was decided to compare students’ proving behaviour on paper and in *Irl Jape*. This was done both as part of the course (“The Observational Study”) and in structured interviews (“The Reflection Study”). Data was also collected on students’ backgrounds, their usage of *jape*, and their success in the course (“The Measurement Study”).

The use of control groups was not possible - on both ethical and pragmatic grounds - and so the Measurement Study focused on data that would enable an exploration of whether different student groups were more likely to use *jape*, and of whether students who made more use of *jape* did better in the course. The main data collection methods for the study were written tests, questionnaires, and automatic logs of program usage. Full details of the instruments, samples, and assumptions for the data collection are provided in Aczel (2000).

In the Observational Study, the work of students was observed over the whole course, following a naturalistic approach (Guba & Lincoln, 1981) in order to understand how *Irl Jape* fitted into the learning context. The bulk of this observation took place in eleven weekly small-group “workshops”, although the teaching also included twice-weekly hour-long lectures, comprehensive course notes and tutorial classes. The workshops provided an opportunity to observe students actively engaged with the subject matter, and to talk informally to them about their understandings and difficulties. Four volunteer students were videotaped using *jape* to assist them in constructing proofs during each of the workshops.

The main aim of the Reflection Study was to test the findings of the Observational Study by putting students in situations similar to those in which important incidents had occurred, seeing if the incidents were replicated, and, if so, obtaining students’ interpretation of the incident. Such interventions were not part of the Observational Study because they would have disturbed the natural flow of the students’ work and directed attention to aspects of the situation that might not otherwise be noticed. In the Reflection Study, therefore, ten students were videotaped using the program in task-based interviews rather than being observed in a naturalistic setting. The interviews took place some five months after the end of the logic course, and shortly before
the end of year exam. Students were given a choice of five topics that they wished to revise, and open questions were used to investigate their conceptions as they worked through activities. Students initially tackled five to ten conjectures or partially-completed proofs on paper, and then the same conjectures were tackled using Jape. The intention was that where the paper attempts had been successful, interface issues would be highlighted when Jape was used; and where paper attempts had been invalid or had stalled, the role of the software in enabling progress would be clarified. The 11 interviews were audio-taped (around 8 hours of paper-based work) and video-taped (about 12 hours of work both on paper and on Jape) and usually lasted around 90 minutes. 10 students were involved - 6 as individuals and 2 sets of pairs. The students were paid for participation, but the value of the session as a means of revising for the imminent exam was also given as a possible incentive. One student took part in 4 sessions, and so was able to cover almost the whole range of topics.

The studies, particularly the Reflection Study, led to the development of a set of descriptive strategies that categorise and explain the patterns of behaviour observed when students attempted to solve logic problems. These strategies, which are inherently pragmatic, can form efficient heuristics for completing proofs.

Although this has extended our understanding of the process of learning logic, the account to date remains entirely empirical and descriptive. In the following sections, attempts are made to use accounts of learning and development to explain the patterns of behaviour and the claims of students.

3 Using the Zone of Proximal Development to model logic learning

As discussed above, research findings show that students have problems understanding and applying formal methods, that generalising and transferring this understanding may take years, but that supportive software and visualisation tools can facilitate this process. One possible interpretation of these findings is that learning logic can act as a precursor to the development of formal reasoning skills, and that the problems facing students can be mediated or scaffolded by providing appropriate support.

This situation seems consonant with the model of the Zone of Proximal Development (ZPD) proposed by Vygotsky (1978). Briefly, the ZPD links the developmental process in children to a social account of learning. Central to the model of the ZPD is the premise that learners will be able to solve more abstract or advanced problems than would otherwise be possible when their learning process is supported or scaffolded by a more able peer. The ‘zone’ denotes the range of activities that the child can perform when supported, but is unable to complete
unassisted; this indicates their potential for development, rather than simply their current ability. In due course, however, it is possible for the learner to ‘internalise’ the kind of interactions that create this zone, thus developing their ability.

The ZPD has been used to justify and explain a number of developments in the area of computer-assisted learning. Its use varies widely, from providing a central thesis upon which the work is founded (e.g., Luckin, 1997) to acting as a passing reference used to endorse collaborative approaches to learning in higher education (as discussed by Crook, 1991). One interesting feature of this use of the ZPD is the way in which the computer has come to be viewed as the more able peer. Although this interpretation of the ZPD seems rather different from its original use, it has been used to explain the effect of supportive software (see, e.g., Crook, 1991; Howe & Tolmie, 1999).

Taking this particular interpretation of the ZPD – rather than just the general model for the long-term development of logical ability noted above – may offer insights into specific observations made during the research. For example,

> For many students, using ItL Jape allowed them to consider many more examples than would otherwise be possible using pencil-and-paper (because the program takes on the task of drawing the proof) and it also guarantees that inadequate proof attempts and incorrect rule applications were immediately challenged.

(Aczel et al, 1999b)

In this particular context, the use of the ZPD seems justified; the expertise in representation and the active challenges certainly imply that the software is acting in the role of a more able peer, providing active and tailored feedback to the learner which will eventually be internalised, thus supporting learning.

Such an interpretation must be made with caution, however, since it makes an important change to the type of situation described by Vygotsky.* In the original formulation of the ZPD, the learner was assisted by a more able peer; here, they are assisted by a system. Need this system be computer based? Given the role of visualisation in this context, it would be reasonable to ask whether a system of representation might also be able to provide support.

Drawing on Ainsworth’s taxonomy of functions of multiple representations (1999), one use of a representation is to constrain the interpretation of a second. In this context, the use of visual cues (such as an ellipsis to denote missing lines of reasoning, or characters to indicate as-yet-unknown propositions) could be interpreted as part of a system (of representation) that provides support for the learner. In effect, these cues provide a layer of representations that supports the

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* See page 31: A commentary on the use of theory in the analysis of the Jape study

Journal of Interactive Media in Education, 2002 (3)
learners’ interpretation of logical notation. (‘Secondary notation’, in Green’s (1989) terminology.) In this sense, the cues could be interpreted as a ‘more able peer’ that supports the learner in making sense of proofs. Importantly, this support would be provided irrespective of whether the representation was embodied in a software application or drawn on paper.

However, although these cues serve a pedagogic role, it would be hard to interpret their role as being ‘collaboration’ with a more able peer. Although it would be possible to compare a student’s ability with and without a particular representation, the problem arises from the notion of this representation providing ‘feedback’, even though it is providing what might easily be interpreted as advice. Whilst the creator of this particular representation is, in effect, providing feedback from a ‘more able’ position, they will be doing so passively or indirectly. In such a situation, it seems inappropriate to draw on a model that is social and, essentially, interactional in nature.

This discussion makes it possible to judge whether it is appropriate to use the ZPD as an explanatory framework for students learning with Jape. The main criterion is that the system should demonstrate a degree of active agency, and should not just passively communicate advice from some ‘more able’ person. The use of ‘degree’ in this criterion suggests that there may well be debate over whether specific cases of system use justify recourse to the ZPD. In this case, however, it seems to offer a framework that can be used to interpret the way in which students work (‘collaborate’) with Jape, although using it to explain the specific role of representations in this process would be inappropriate.

In addition to these conceptual issues about the appropriateness of the model, there are a number of pragmatic problems that limit the usefulness of the ZPD. Although the ZPD seems promising as a general explanation of the research findings concerning use of the software, a finer-grained analysis identifies further difficulties. Splitting the learning process into increasingly abstract steps or layers is not straightforward. As noted above, the strategies that were observed evolved pragmatically, and gave little insight into any conceptual or cognitive development that might accompany their use. This makes it particularly difficult to envisage any notion of ‘direction’ in learning these topics, which raises the question of whether it is feasible to map out a zone against which progress might be interpreted. (Vygotsky suggested (1962) that this might not be an unusual problem.)

At a simple level, however, the observational study suggests that students learn in the following steps:

• concept acquisition (lectures and texts)
• use of software (labs); paper & pencil problem solving
• trial and error (as evidenced by quotes such as, “he doesn’t know what he’s doing... he’s proving them but he doesn’t know what’s going on.”)
• development of ad hoc heuristics for problem solving
• abandonment of heuristics in favour of more general strategies

This model is essentially chronological, although it also suggests a move from surface learning (of facts or routines) towards a deeper conceptual understanding of the topics. However, this implied model of conceptual development does not seem to hold in practice. Students may make a leap of understanding when initially presented with the concepts in a lecture, whilst others may develop concepts through trial and error, only later referring these back to content delivered in formal teaching settings.

Moreover, although this model is less general than simply saying that studying logic allows the development of logical thinking, it still says nothing about the process of learning specific topics, concepts or rules. These steps are neither strictly linear nor independent, and learners may well be at different stages with respect to different rules. If the ZPD is to be used to model learning, it becomes important to have some sort of ‘map’ that enables comparisons of current and assisted ability to be made. In other words, it becomes important to have some structured form of representing ability (specifically, the ability to use and understand rules and concepts) in this domain. Three different types of relationships between rules are possible:

1. The learning processes for different topics are sequential. In this case, the learning process for each rule can be viewed as a series of steps within one overarching ‘map’ that describes the entire process of learning logic using Jape. (Figure 1)

   ![Figure 1: sequential rule learning](Image)

2. The learning processes are independent. In this case, the ‘map’ is fragmented, and the ZPD can only be used to model the acquisition of each rule separately. (Figure 2)

   ![Figure 2: independent rule learning](Image)
3. The learning processes are mutually dependent. In this case, the ZPD no longer maps linear processes, but a multi-dimensional one. This means that the overall learning process for logic is inherently complex, with each step in the learning process being influenced by what the students already understand. (Figure 3)

![Figure 3: inter-dependent rule learning](image)

The first possibility can be discounted, not least because the Observational Study revealed that preliminary sessions introduce a number of rules simultaneously, and this precedes the workshops with Jape where strategies for rule application are developed. Similarly, the second possibility can be discounted if the students make any kind of analogical inferences from one rule to another, or if the strategies for use of any rule draw on knowledge of others. Evidence for this was provided by the Reflection Study:

*Some of these rule-specific strategies help students to choose between rules; for example, «if there is a choice between vE forwards and vI backwards, try vE first». The student Kusi described this as the “precedence” of vE over vI.*

(Aczel et al., 1999b)

Moreover, several rules are introduced through derivation from others, such as the definition of \( A \lor B \) (“either \( A \) or \( B \) is true”) as \( \neg(\neg A \land \neg B) \) (“it is not the case that neither \( A \) nor \( B \) is true”).

Having eliminated the first two options (Figures 1 and 2), it can be concluded that the process of learning first order logic follows the third model, requiring an account of the inter-relationships between rules to be drawn up before the notion of ‘difficulty’ in logic learning can be properly explained. The implication of this is that as well as lacking a meaningful measure of the relative ‘distance’ between developmental steps, it is also impossible to elaborate what the ‘shape’ of this space is. It may be possible for future work, perhaps using a methodology such as grounded theorising (Strauss, 1987), which focuses on understanding the complex inter-relationships between concepts as encountered and used in real contexts, to develop a more useful map. Until this happens, however, the usefulness of the ZPD as a model for learning logic will be limited to general conclusions about logical development. Lacking a clear model of the
process of learning to reason formally, the ZPD cannot be used to explain students’ progress. It can, of course, be used to explain differences in students’ ability when working alone or in collaboration, but only in terms of the current general, poorly articulated model of the domain.

4 Using cognitive dimensions as a basis for comparing the difficulty of rules

Green's cognitive dimensions (1989) characterise the way in which information artefacts structure and represent information, and are intended to support the software design process. These address important aspects of systems' usability, such as the ease with which changes can be made (viscosity), the degree to which links between components are made explicit (hidden dependencies), how long the user can postpone strategic decisions until all implications are known (premature commitment), and so on. These descriptors are used to analyse 'ideal' (hypothetical) uses of a system, with the intention of understanding the pay-offs between different design options.

An obvious extension of this concept is to use the dimensions to describe the relative usability of specific components of systems; indeed, Kadoda et al. (1999) have followed this approach in order to identify the features of theorem proving software that support learnability. In this case, cognitive dimensions will be applied to the process through which rules are applied to proofs within the context of Jape. Such an analysis may provide some explanation of the relative difficulty of using different rules – one of the issues identified when considering the ZPD above. Table 1 shows how some of the rules implemented in Jape compare in terms of a relevant subset of cognitive dimensions. Note that because no standard metric has been devised for the dimensions, these comparisons should be interpreted as being based on a relative ranking.

<table>
<thead>
<tr>
<th>Rule</th>
<th>Explanation</th>
<th>Hidden dependencies</th>
<th>Abstraction level</th>
<th>Premature commitment</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Rightarrow ) forwards</td>
<td>Turns ( A \Rightarrow B ) into ( B )</td>
<td>None</td>
<td>Low</td>
<td>None</td>
<td>Moderate</td>
</tr>
<tr>
<td>( \Rightarrow ) backwards</td>
<td>Given ( A \Rightarrow B ), a section of proof will be added (before ( A \Rightarrow B )) that requires ( B ) to be deduced from ( A )</td>
<td>Moderate</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>( \vee ) forwards</td>
<td>If ( C ) follows from ( A \vee B ), then user must show that ( C ) follows from ( A ) and ( C ) follows from ( B )</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>( \vee ) (R) backwards</td>
<td>Can be applied to justify ( B \vee A ) if ( A ) already features in the proof. (( B ) does not need to feature elsewhere.)</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 1: Examples of differences in rule applications in Jape
Evidence to support the fact that students encountered problems with premature commitment and abstraction, for example, can be found in the analysis of the Reflective Studies.

> It seemed to take many students some time to realise that unexpected results were often attributable to a line not being selected before a rule is applied. Also, several students suggested that they were confused at certain points in particular conjectures about whether, when they selected a rule, it would be applied “forwards or backwards.”

(Aczel et al., 1999b)

This problem is well illustrated by comments from one of the students, referred to as Caroline. The first concerns the problem of guessing from the interface whether or not a rule would be applied forwards or backwards (premature commitment):

> It’s working opposite to the way I would. It’s working backwards.

Similarly, a second quote concerns whether applying the rule, \( \land \neg E(L) \), selected or removed the left-hand-side of the formula:

> Which one does it keep and which one does it chuck away?

This highlights some of the advantages and disadvantages that arise from the use of a software tool. On the one hand, Jape’s use of visualisation introduces additional premature commitment (by assuming which line rules apply to and forcing students to guess whether the rule is an introduction or elimination, rather than forward or backwards). On the other, it introduces secondary notation (such as the ellipsis and justifications of moves, and also in the form of feedback on errors) and reduces viscosity by allowing moves to be ‘undone’ in order to make changes. However, as noted in Table 1, not all rules are equally easy to undo, with some (such as \( \lor E \) forwards) requiring additional information to be given in order to restore the previous step.

As noted above, one of the outputs from the study was a set of strategies that students adopted in order to complete proofs. These strategies are ‘meta-moves’; they help the student to decide which rule they should be applying next. Because these strategies are essentially complexes of the above rules, it is proposed that in the same way that rules can be analysed in Jape, the strategies used to determine which rule to apply can also be analysed using cognitive dimensions. Table 2 illustrates this for a selection of the strategies developed from the Reflection Study.
Table 2: An analysis of strategies for proof construction using cognitive dimensions

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Hidden dependencies</th>
<th>Abstraction level</th>
<th>Premature commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>«Break up implications in the conclusion»</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>«Look for the 'main symbol' in the most complicated line. Find the same symbol in the list of rules. Try one of the matching rules. Undo the rule if the display doesn’t look right... and try another»</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>«Make an assumption»</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

Having demonstrated that this mapping can be carried out, the next question to be asked is, does this help construct a model of learning? One implication is that it is possible to predict that certain strategies – i.e. those that are consistently ‘low’ in the table above – will be easier to use successfully. Those that are learnt early on but which have fairly complex implications (such as making an assumption) are likely to lead to difficulties.

The way in which these strategies are used to apply increasingly complex logical rules (as indicated by consistently high ratings in the third to fifth columns of Table 1 – a high rating in the sixth reflects the difficulty of undoing steps, e.g. to correct mistakes, and so may not be relevant in certain contexts) may provide an insight into the learning process, allowing predictions to be made about the versatility of certain strategies and the relative difficulty posed by specific proofs.

Finally, this mapping process provides an explanation of a role for visualisation in learning logic:

> Strategy development seemed most successful when the visible effects of an action were not only sufficient to allow students to make an informed decision about the utility of the action, but were also subtle enough to place the onus of strategy-development on the student. (Aczel et. al., 1999c)

Cognitive dimensions provide a way of estimating the ‘size’ of the scaffolding that Jape offers, albeit one limited by the same provisos about relative rankings and combining categories made for the analysis of applying rules. The implication of this is that if we can gauge how much support a student needs, it may be possible to adjust Jape to provide just enough scaffolding for problems to be pedagogically challenging rather than too easy or inappropriately complex.
Returning to the point made above, working with *Jape* introduces both advantages and disadvantages. It is reasonable to ask whether the advantages outweigh the disadvantages. A comparison can be made between the application of rules either with or without the support provided by various elements of *Jape*, particularly in terms of the use of visual cues such as secondary notation. (Table 3)

Table 3: A comparison showing the 'size' of scaffolding provided by *Jape*’s visual clues

<table>
<thead>
<tr>
<th>Feature</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification provided on right hand side of line of proof</td>
<td>Secondary notation increased, abstraction decreased, hidden dependencies decreased</td>
</tr>
<tr>
<td>‘Placeholder’ (e.g. _P) introduced when rules are applied without reference to a particular line</td>
<td>Secondary notation increased (probably unhelpfully), abstraction increased, hidden dependencies increased</td>
</tr>
<tr>
<td>Error messages (reports that could be interpreted by the developers)</td>
<td>Secondary notation increased (unhelpfully), abstraction increased, hidden dependencies increased</td>
</tr>
<tr>
<td>Explanatory messages (intended to advise the learner)</td>
<td>Secondary notation increased, abstraction may decrease, hidden dependencies may decrease</td>
</tr>
<tr>
<td>Ellipsis to indicate missing steps or justifications</td>
<td>Secondary notation increased, abstraction decreased</td>
</tr>
<tr>
<td>Use of menus divided into 'Introduction' and 'Elimination' rules (rather than 'forwards' and 'backwards' rules)</td>
<td>Abstraction increased, hidden dependencies increased</td>
</tr>
</tbody>
</table>

What this highlights is that, for most of these features, the situation is improved: either the relative difficulty is decreased, or extra support (e.g. from secondary notation) is provided. However, it should be noted that the list of features in table 3 is indicative, not exhaustive; as such, this kind of analysis will be limited to identifying areas of strength and weakness, rather than providing any absolute judgement about the ‘good-ness’ of the tool.

In summary, then, cognitive dimensions provide a useful vocabulary for describing relative complexity and degrees of support. Although the lack of a metric for these dimensions means that the analysis relies on rank ordering of options, this still provides some insight into the difficulty of concepts and strategies, and the type of support provided by *Jape*’s use of visualisation.
5 Popper–Campbell Psychology

Another model that may help in accounting for the pattern of students’ engagement with formal reasoning is based on the work of Karl Popper. Developments of this model (Aczel, 1998) suggest that learning can be analysed in terms of the trial-and-improvement of psychological entities called “strategic theories” in response to problems of special interest to the individual – “concerns”. 10

Popper’s critique of the “bucket theory of mind”, his insistence that what can be learned is heavily dependent on the individual’s prior theories “of persons, places, things, linguistic usages, social conventions, and so on” (Popper, 1963) and his view that “knowledge” in the public sense comes about through complex intersubjective processes, are clearly in resonance with the work of Vygotsky. Yet it should be pointed out that what is described here is very much a psychological rather than a sociological perspective. In contrast to some interpretations of Vygotsky, it is assumed that it is the individual – and this individual’s interactions with the worlds of physical objects, ideas, and people, mediated by language, social forces, culture and history – that is the focus of study, rather than language, social forces, culture and history themselves.

Rather than learning consisting in the passive, steady, repetitive accumulation of information, there are active processes of decoding and sifting, in which existing theories are modified by creative, conjectural, discontinuous trial-and-error-elimination. Campbell (1960) describes a mechanism called “Blind-Variation-and-Selective-Retention” (BVSR) for such imaginative processes, in which, by analogy with evolution by natural selection, there is “a mechanism for introducing variation”, “a consistent selection process”, and “a mechanism for preserving and reproducing the selected variations”. Campbell also suggests that mechanisms shortcutting BVSR were themselves created by BVSR.

It is important to note that a key feature of this psychological perspective is that creative theory-formation processes do not occur in isolation, but in response to the selection pressures afforded by problems of special interest to the individual – a “concern”. Concerns would include desires, motivations and fears. By attempting to address one’s concerns, new strategic theories are constructed from old, and these may in turn generate new concerns. In the research described here, the main concern would be to prove conjectures.

One subtle aspect of Popperian psychology is that action, context and theory are intertwined. Students have myriads of complicated, contextual and implicit theories (taken as constructions of reality), created from a wide variety of experiences and concerns. There is often a strategic nature to these theories in that they solve problems.

10 See page 31: A commentary on the use of theory in the analysis of the Jape study

Journal of Interactive Media in Education, 2002 (3)
For example, students tended to interpret Jape’s representation of an incomplete step as indicative of an incorrect step. One student said, “When _A and _B [Jape’s representation of as-yet-unknown propositions] came up you knew you were on the wrong track”. This interpretation constitutes a constructed expectation or theory about what constitutes progress in reasoning, but within Popperian psychology it can also be seen as an elementary strategy for proving conjectures - «If you get _A and _B, undo the step».

Conversely, an action, strategy, plan, heuristic, procedure or process can be considered as a theory, in that it incorporates expectations about what is. Hence we refer to strategic theories. For example, the strategy, «Break up implications in the conclusion», can be seen as a simplistic reference to a theory about reasoning in Natural Deduction that propositions with an implication in the conclusion are soluble by first applying the rule \( \rightarrow I \).

In short, then, the learning of Natural Deduction using Jape would consist of the trial-and-improvement of proof strategies. Some of the more or less readily identifiable strategies that students might be using to help them construct proofs are rule-specific, such as «If there is an arrow as the principal operator in the conclusion, break up the conclusion using \( \rightarrow I \)». Some of these rule-specific strategies help students to choose between rules; for example, «If there is a choice between \( \lor \) forwards and \( \lor \) backwards, try \( \lor \) first.». The student Kusi described this as the “precedence” of \( \lor \) over \( \lor \). In contrast to rule-specific strategies, there appear to be strategies that might be called global strategies; for example «When reasoning forwards, check if the lines produced are useful in obtaining the conclusion.»; «When reasoning backwards, check if the lines produced are provable from the premises.»; and «The principle operator in a line is the only operator that determines the legal rules applicable to that line.».

It could be argued that the proof strategies represent no more than an ad hoc collection of “rules of thumb” - purely mechanical responses to a limited set of straightforward syntactical inputs - that demonstrate little of the deep understanding that an experienced logician might have, and show little regard for the circumstances in which they might fail. However, Popperian psychology would emphasise that these strategies incorporate expectations about what a proof should look like, about why a particular rule might be applicable in certain circumstances, and about what might or might not be provable; and these expectations constitute nascent knowledge.

In the remainder of this section, we consider what this Popperian psychology may have to tell us about the role of the computer, about why the software seems to be able to help some students more than others, and about why certain logical rules seem to be harder than others.
The role of the computer

The introduction of the computer has a profound impact on proof strategies. For example, it appears that novices’ attention on paper is unfocussed – there are no universal strategies for deciding which line to attend to. But with the computer, students readily construct the strategy «Only try to prove the line directly below the ellipsis [the three dots that Jape uses to indicate missing lines]».

Another example is of students who have been following a paper-based strategy akin to «To create the line ‘P\(\land\)Q’, write it down, find P (on line \(x\), say), find Q (on line \(y\), say), and then write down the justification \(\varphi \), \(x\), \(y\)» constructing, when using the computer, a strategy akin to «To create ‘P\(\land\)Q’, find a more complex line containing it, and find some rules that break the line down». The concern has changed from, “How do I justify this line I’ve written down?”, to, “Which rule do I apply to which line to generate this line?” For example, the student Caroline is heard to ask, “How do you get the ‘ands’ to come into it?”

Two fallback strategies were noticed that are unavailable on paper. It was rare to see students using «Click on one of lines; keep on trying rules; try a different line», but when more sophisticated strategies failed, quite a few students fell back on the “symbol-matching strategy”:

«Look for the ‘main symbol’ in the most complicated line. Find the same symbol in the list of rules. Try one of the matching rules. Undo the rule if the display doesn’t look right (criteria for which might include any large, unexpected increases in the length of the proof, the number of boxes, the number of gaps in the proof, the appearance of unfamiliar symbols); and try another.»

In fact most of the students who were observed to be fixated on reasoning forwards on paper soon discovered (using this symbol-matching strategy) that the inefficient rule “make an assumption” was unnecessary and that «apply \(\Rightarrow\) I backwards» generated assumptions automatically.

One student drew attention to the almost mindless character of symbol-matching strategy: “He doesn’t know what he’s doing. … He’s proving them but he doesn’t know what’s going on.” Yet these were very much strategies of last resort – on the whole students seemed motivated to develop ever more efficient proof strategies, even though these require debugging and greater care in application.

The value of the software to the students could therefore be characterised as allowing students to consider many more examples than would be possible using pencil-and-paper, and to debug proof strategies that depend on incorrect conceptions of individual rules and inadequate conceptions of the requirements for a complete proof.
Why the software seems to be help some students more than others

What follows is a particular argument based on the Popperian model, described in order to illustrate the style of analysis – other arguments are possible within this model. The analysis has been simplified quite a bit for the purpose of illustration. (A more detailed explanation of this argument, with examples of individual students’ activity and talk, is available in Aczel, 2000.)

When considering why the software helps some students more than others, four groups of users can be considered, delineated with respect to their prior knowledge of the rules:

1. Those who know the name of the rule they want to apply, but are not necessarily aware of what the precise effects of the rule might be.
2. Those who know how they want the transformed proof to look, but are less sure about the name of the rule that achieves this transformation.
3. Those who have a limited grasp of the rules and are trying to work out from the output of the program how they can be used.
4. Those who have never met the rules before.

Group 1 and Group 2 students may already have some experience of tackling paper proofs before using Jape; Group 3 and Group 4 students have not. In fact, Group 4 students are not target Jape users at all.

Group 1 students - the nominalists - know the name of the rule, but are not necessarily aware of what the effects of the rule might be. While they may sometimes be surprised by the effects of applying a rule, such surprise is not automatically to be taken as indicative of error; only if further reasonable moves are blocked would error be suspected. The strategy for choosing the rule would be the assumed culprit.

On the other hand, Group 2 students - the causationists - know what they expect to see, and would suspect error if they did not see it. The name of the rule is of secondary importance. Typically, when such students have constructed the proof on paper, they ask themselves as they write down the justifications, “What is the rule that describes the step I’ve just carried out here?”, rather than (say) writing down the justifications and trying to remember how the relevant rule works. Group 2 students therefore have a difficulty with Jape in that they are more comfortable carrying out transformations on a proof without being forced to use a named transformation. Their main difficulties centre on getting the interface to produce the effects they
want to see, and finding a way of remembering which rules correspond to the desired visual effects.

Note that this classification of students into Group 1 if they know the name of the rule they want to apply, and Group 2 if they know the step they want to apply, may not be applicable across all rules; but these user groups can serve as broad categories that might help in interpreting specific instances of student behaviour.

Each of these groups face a different strategic-theory problem situation; these will be outlined in turn for Groups 1-3 (Group 4 not being a target group of users). For example, at each stage of a paper proof, a Group 1 student:

(i) chooses a rule to implement (using what might be called a “rule-choice strategy”),
(ii) implements the rule (using a “rule-implementation strategy”); and
(iii) justifies new lines (using a “justification strategy”):

![Figure 4: Paper proof – Group 1 students](image)

The next question to consider is how this situation differs when using Jape. Jape takes care of the justification strategy, and makes the rule-implementation strategy much easier. It also provides feedback that can be used in an assessment of whether the new proof constitutes a movement in the direction of proof completion (what might be called a “progress-assessment strategy”), so as to debug their rule-choice strategy:

![Figure 5: Jape proof – Group 1 students](image)
By contrast, for each stage of a paper proof, a Group 2 student:

(i) chooses a step to implement (using a “step-choice strategy” - note that we refer here to a “step” rather than a “rule”, because a Group 2 student’s strategy for constructing proofs does not initially require them to know the name of the rule);
(ii) implements the step (using a “step-implementation strategy”);
(iii) finds the rule corresponding to the step (using a “step-name strategy”); and so
(iv) justifies new lines (using a justification strategy, as for Group 1 students).

Figure 6: Paper proof – Group 2 students

Again, the situation differs when using Jape. Jape provides feedback that can be used in a progress-assessment strategy. The program also takes care of the justification strategy, but it does not allow the user to implement a step without selecting the corresponding rule. Hence with Jape, the step-name strategy has to be used before using the step-implementation strategy, unlike their approach for paper-based proofs.

Figure 7: Jape proof – Group 2 students

So even though they have good progress-assessment strategies (they know what they expect to see) Group 2 students may find it difficult to improve their step-choice strategies using Jape because their step-name strategies are undeveloped. Their typical fallback strategy on paper «When all else fails, assume something» is particularly unhelpful in Jape. Consequently, Group 2 students appear to gain least from the software.

For each stage of a paper proof, Group 3 students will make best (but idiosyncratic) use of their limited knowledge to progress. Since they receive no feedback except through comparison with lecture notes and comments from tutors, it is difficult to predict how their strategies improve, or even whether they will end up as Group 1 or Group 2 students.
However, when Group 3 students start using Jape, this idiosyncratic process can be dramatically transformed. In order to progress, they must select a rule and use the feedback to determine if it was a good choice. Hence it is likely that if they are successful in learning from ItL, Jape they will turn into Group 1 students rather than Group 2 students. But this transformation crucially depends on them having a viable embryonic rule-choice strategy (such as the symbol-matching strategy), and this can place strain on the memory because there will often be at least four possible rules to check (introduction and elimination rules for a premise and a conclusion), and sometimes more (if there are multiple premises or the possibility of proof by contradiction). So it is particularly important for Group 3 students to be systematic, to avoid any additional complexity, and to recapitulate soon afterwards in another form what they have learned. In the short-term, these students have the potential to gain most from Jape.

The above analysis can go some way to explain observed student behaviour in individual case studies, suggests potential gaps in students’ knowledge that may remain (rule-implementation and justification), and produces testable hypotheses about the impact of changing aspects of the software on different user groups.

*Why certain logical rules seem to be harder than others*

Some rules appear to be harder than others: conjectures involving implication and conjunction tended to be seen by students as the easiest conjectures to prove; the Disjunction topic (in conjectures which could also involve implications and conjunctions) was next; Negation and Quantifiers were held in about equal dread. This perception is matched by measures of the time spent per proof attempt, and by success in written tests.

Unlike the cognitive dimensions model (earlier), or the cognitive load model (below), it has to be admitted that the Popperian model has no ready-made explanations for this. Nevertheless, it is possible that measures could be developed that attempt to capture (in something akin to the cognitive load model) the complexity of the proof strategies that students are typically using for a particular rule. It is also possible that the development of different proof strategies could be compared with respect to their reliance on a number of basic proof strategies that are more “basic” in some sense (a criterion something akin to “abstraction level”), or with respect to their reliance on properties of the proof and the interface that are more or less implicit (a criterion akin to “hidden dependencies”), or with respect to their reliance on an order of actions that is relatively inflexible (a criterion akin to “premature commitment”).

To summarise, the weakness of the Popperian model is that it does not provide off-the-peg measures or dimensions. However, the strength of the model is that, by emphasising that new strategic theories are constructed from old and in response to an individual’s concerns, attention
is immediately drawn – as with the Vygotskian approach – to the student’s prior knowledge and to the precise sequence of learning activities. For example, it turns out that the perceived and measured order of difficulty of the topics matches the order in which the rules were introduced in the lectures, the order in which the rules were practised on paper, and the order in which the conjectures were presented in the software. This “order of difficulty” may very well depend on some absolute properties of the rules themselves, but the strong possibility that it is dependent too on the student’s prior experiences should not be forgotten.

6 Cognitive Complexity

The fourth (and final) approach to explaining learning that will be considered in this paper is that of cognitive complexity. This approach focuses on problem solving activities, taking into account factors such as prior knowledge and ‘cognitive load’. The idea of cognitive load rests on the assumption that people’s capacity to process information is limited (Sweller, 1988); in other words, that the more a learner tries to hold ‘in their head’ at any point, the harder their learning will become. (This idea clearly draws upon the notion that there are analogies between the human mind and computers.) It is also assumed that some activities entail a higher cognitive load than others, so that (for example) integrating information from multiple sources is harder than studying a worked-out example (Sweller, 1989).

Within the context of this study, the relatively constrained and well-defined nature of the domain means that it is possible to apply the idea of cognitive load to the rules used during proof construction. For example, it could be argued that the rules \( \rightarrow E \) and \( \rightarrow I \), when applied on paper, make similar demands on working memory:

| \( \rightarrow E \) | From A and A \( \rightarrow E \) B we can conclude B |
| \( \rightarrow I \) | If you assume A, and prove B, we can conclude A \( \rightarrow I \) B |

For \( \rightarrow E \), for example, one might hypothesise (in the manner of Sweller, 1988) the following demands: “hold A in memory”, “hold A \( \rightarrow B \) in memory”, “apply this rule to deduce B”. For \( \rightarrow I \), the demands might be represented as, “hold A in memory”, “hold B in memory”, “apply this rule to deduce A \( \rightarrow B \)”.

So all other things being equal, one would expect students to fare equally well in implementing these rules.
However, the software changes the situation. \( \rightarrow E \) still requires the recognition of the situation “\( A, A \rightarrow B \)” in the premises, and the expectation that “\( B \)” will result from applying the rule. But in addition, the software requires a selection; the student has to choose the selection from, the “\( A \)” in the premise, the “\( A \)” in “\( A \rightarrow B \)” “\( A \rightarrow B \)” “\( A \rightarrow B \)” “\( A \rightarrow B \)” “\( B \)” in “\( A \rightarrow B \)” “\( B \)” in the conclusion. In fact the selection should be “\( A \rightarrow B \)” but either failing to make a selection or selecting the “\( B \)” in the conclusion create confusing results. The implication of this is that the cognitive load associated with \( \rightarrow E \) goes up using the software.

With \( \rightarrow I \), on the other hand, the cognitive load is dramatically reduced. Not only is it not necessary to decide what to assume, and there is no problematic ambiguity about selection, but the consequences of applying the rule (in terms of both logical form and layout) are automatically handled by the computer. The only task is to recognise the form “\( A \rightarrow B \)” in a conclusion, and apply the rule to it. The consequences do not need to be worked out by the student, because this particular rule-application is nearly always productive.

From roughly equal parity on paper, the cognitive complexity of the \( \rightarrow E \) rule can be as much as five times that of the \( \rightarrow I \) rule (based on measures such as those in Sweller, 1988) when learning is supported by the software. The empirical results indeed suggest that \( \rightarrow I \) is much more readily used – and used successfully – at the computer than on paper.

Some important caveats

Yet although this analysis produces an accurate prediction of the increase in accessibility of the \( \rightarrow I \) rule, some weighty assumptions and simplifications have been made.

For example, it is assumed that each of the demands described above are of the same size, yet our representation of the paper-based version of the \( \rightarrow E \) rule as “hold A in memory”, “hold A \( B \)” in memory” and “apply this rule to deduce B” could be rather an oversimplification. Perhaps a better representation is “identify A as a premise”, “identify A \( \rightarrow B \)” as a premise”, “conclude B, justified by the rule \( \rightarrow E \)” But this still leaves many questions unanswered: What are the demands of “identifying a premise”? How much harder is it to identify “\( A \rightarrow B \)” than “\( A \)”?

Moreover, if we are considering how students construct a proof of conclusions from premises rather than whether students can validate a given proof, we have to ask - what formal rules (e.g. Braine, 1978), cognitive schema (e.g. Chi et al, 1982) or mental models (Johnson-Laird, 1983) motivated having B as a conclusion in the first place?

Meanwhile, the representation of \( \rightarrow I \) is even more questionable. What motivates the making of assumptions? Some students would appear to make assumptions as a last resort, when no other forward moves were possible. Other students would use the existence of conclusions of the
form “A → B” to trigger I. Whether “A” is guessed or calculated must surely have a large impact on the memory demands of this rule. Moreover, does representing assumption scope by drawing boxes place demands on cognitive processing capacity? What is the effect of having to leave a space of indeterminate size for lines to link A to B?

Clearly, there are several fundamental problems that can be identified with this approach. Leaving aside the assumption that the mind-computer analogy is justified, it is clear that the notion of weighting is based on a fairly arbitrary model of the process of proof construction, with no indication about the level of granularity that this model should be constructed at. Additionally, whilst the analogy remains internally consistent for analysing the way in which given information is processed, it has little to offer as a way of explaining the spontaneous creation of additional information, for example in the form of new assumptions. Moreover, the theory has little to say about the modality in which information is presented, something which clearly does affect learning (Ainsworth, 1999). As such, its contribution to understanding the role of visualisation in the process of learning formal reasoning is inherently limited.

Nevertheless, this model does have some empirical evidence from cognitive psychology; and in the Jape research, the time spent on each proof correlates with the textual length of the statement of the conjecture, which is a rudimentary measure of complexity for simple proofs. The approach also helps to explain why students had difficulties with rules involving examining multiple cases (e.g. “∀E forwards”), incomplete steps (e.g. “∃E backwards”) or ambiguities about left and right (e.g. “∀E forwards”). It is also possible that when students attempted the Negation and Quantifier topics using the software, some abandoned the process of properly implementing the rules with high cognitive loads in favour of a much less demanding click-and-see trial-and-error approach. However, it must be concluded that this model has not produced convincing accounts of the actual processes underlying students’ reasoning, particularly in the more complex proofs, and especially not those involving negation. Nor does it succeed in explaining students’ reluctance to use justifications, structural aspects of proofs, and semantic considerations as ways to reduce cognitive load in sometimes quite dramatic ways.

Despite the apparent existence of a “comprehensive theory in psychology to explain all the main varieties of deduction” (Johnson-Laird & Byrne, 1991), it is far from clear how students are reasoning in this formal context. Rips (1994) points out that the study of reasoning within experimental psychology has focused on rather specialised informal deduction tasks. In particular, the typical approach is to ask subjects to evaluate the validity of simple inferences or to draw conclusions from given premises. Yet the task that is faced by novice logicians is rather different – it is to construct a valid formal proof from given conclusions to given premises. It is at this point that the problems of cognitive complexity, which was originally developed as a way of explaining the benefits of learning from worked-out examples, become clear.
7 Conclusions

The problem identified at the outset of this paper involved re-visiting accounts of students learning logic using Jape in an attempt to make these explicable and meaningful. In order to do this, a number of theoretical interpretations of the situation were considered. What, then, can be concluded, both about the situation being analysed and about the utility of these theories?

The first conclusion to draw is that, to a greater or lesser degree, each theory considered offered a useful but partial perspective on the situation. This is, perhaps, unsurprising; each originated from a different set of values and concerns, and thus makes sense of the phenomena in a way that emphasises certain aspects at the expense of others.

The notion of the ZPD, for example, has provided a useful way of reconsidering the way in which the students learn with Jape. One of the things that this theory emphasises is that the important word in the preceding sentence is ‘with’, which might have been replaced by ‘from’. Whilst the ZPD cannot adequately explain the fine-grained detail of the learning process, preventing it from becoming a detailed model of this situation, the notion of working with a more able peer and learning by internalising these social interactions recurs throughout the paper. In the section on Cognitive Dimensions, for example, the role of secondary notation and other cues as a way of providing feedback on actions is explored. Similarly, in the section on Popper-Campbell psychology, the process of revising strategies rests, at least in part, on the way in which students learn from what Jape does, and by working with the software to try out different approaches that, were they working on paper, would be beyond their means (either conceptually, if Jape is used in a trial-and-error manner, or in terms of number, given that Jape allows more examples to be considered) to attempt. Thus whilst the ZPD cannot, in itself, explain all of the phenomena observed in the studies, it does provide a way of framing the subsequent interpretations and taking a broader view of the learning process.

With the Popperian model, unlike the Vygotskian approach, learning mechanisms are examined in terms of the explicit analytical tools that are the hypothesised strategic theories and concerns. These qualitative tools enable detailed conjectures to be made about how a different instructional sequence, a different implementation of the propositional calculus, or changes to the interface might affect learning outcomes. For example, the analysis of users with differing prior subject knowledge can go some way to explain the relative perceived difficulty of the topics. In particular, that analysis would suggest that for Group 3 students, features of the interface that contribute to the systematic testing of embryonic rule-choice and progress-assessment strategies

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6 See page 31: A commentary on the use of theory in the analysis of the Jape study
12 See page 33: A commentary on the use of theory in the analysis of the Jape study

Journal of Interactive Media in Education, 2002 (3)
would be appreciated; features that were irrelevant to this testing would be ignored; and features that inhibited this testing would be problematic. Examples of the latter features are significantly more common in the Quantifiers topic than in the other topics; such features also appear in the Disjunction topic to a lesser extent. In the case of the Negation topic, the fallback symbol-matching rule-choice strategy is inadequate to allow students to develop two particular strategies that are key to proving these conjectures. Thus by concentrating on the students’ internal process of meaning-making, this particular theory allows predictions to be made about how specific changes will alter what students learn. As such, this specific internal interpretation of the situation complements the general, social interpretation offered by the ZPD.

The idea of Cognitive Dimensions changes the focus yet again. It, too, could be construed as a social model; as with the ZPD (as used in this context), it focuses on the interactions between user and system. However, whereas the ZPD proved difficult to use at fine-grained levels of analysis, these dimensions only work at this level. Whilst problems remain, particularly in terms of the subjective and relative way in which they are measured, the dimensions do offer a way of explaining and theorising about why certain rules or strategies were difficult to use, either on paper or with Jape. It also provided direct insights into the role of visualisation in this process, something that the other theories touch on only tangentially, if at all. By comparing the ways that learners interpret and interact with visual representations (as opposed to syntactic ones), it provides an insight into which features of Jape support and which hinder learning – insights which are of wider relevance to researchers working in the area of visual reasoning. In doing so, it also overcomes the problems of only supporting relativistic measures of the dimensions. Thus this approach has direct and immediate benefits, for example in terms of explaining why the use of the symbol “_P” as a placeholder hindered learning, whilst use of the ellipsis supported it. It also provides the prediction that rules such as “→ E forwards” should be easy to use in Jape, whilst ” I(R) backwards” is likely to be difficult, allowing teachers to direct their attention towards supporting specific topics. In addition, this offers a way of anticipating the impact that changes in the software design, and in particular, of the way in which visual representations can be incorporated into software in order to support learning.

Finally, it must be concluded that although the notion of cognitive complexity appears, at first impression, to be well-suited to explaining learning in this context, it actually has little to offer. There is certainly a resonance between the notion of cognitive load and some of the measurements inherent in the use of cognitive dimensions, but the approach fails to move beyond relativistic measures to anything more objective, and lacks the versatility of considering different aspects of the process of interacting with the system.

To conclude, these separate analyses allow a much richer explanation to be offered of the situation under study. The introduction of a software tool, Jape, that uses visualisation...
techniques to support formal reasoning changed learning in a number of identifiable and explicable ways. Firstly, it made certain proof-solving approaches easier, and others harder, as a result of the way that the interface was structured and information was represented. Specifically, it helped in ways such as cueing students in to issues such as missing lines that might otherwise have been missed, whilst hindering through the introduction of notation that misled either by making the notation more abstract or by appearing overwhelming in length or complexity. The way that students used the software – and the extent to which it supported or inhibited their learning – depended in part on the way that they understood proof construction. Those who knew the names of rules (but not what its precise effects might be) were able to learn effectively from Jape by trying these rules out, and ‘undoing’ them if they were unhelpful. Those who knew what they were trying to achieve, but did not know exactly what this ‘move’ was called, had problems, since the interface relied on using names to apply rules. Finally, those who had a limited grasp of the rules and were attempting to learn from their exploration of the software either had real problems or else turned into ‘Group 1’ students (i.e. those who knew the names but not necessarily the effects).

With all of these students, the learning process involved building up patterns of interaction that ‘worked’; these strategies were developed and refined on the basis of whether or not they were useful in completing proofs. Moreover, it was possible to explain why some of these strategies were harder to use than others, with approaches such as, «Break up implications in the conclusion» being a safe, easily understood tactic, whilst the strategy «Make an assumption» involved guessing ahead about how the assumption might be used later in the proof and also added new, complicating information into the proof structure. Drawing all this together, it seems that the way in which students developed these strategies and thus learnt about formal reasoning involved working with Jape to test different approaches and try out unfamiliar rules, gradually internalising the feedback that resulted from their interactions with the system.

At the outset, it was possible to say what happened when students started using Jape to learn formal reasoning. Through the analysis outlined above, it has proved possible to develop these fragmented facts into an explanation which, although doubtless still incomplete and worthy of further elaboration, nonetheless provides a meaningful and credible account of how this learning took place.

Acknowledgements

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\textsuperscript{4} See page 30: A commentary on the use of theory in the analysis of the Jape study

Journal of Interactive Media in Education, 2002 (3)
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² See page 30: *A commentary on the use of theory in the analysis of the Jape study* Journal of Interactive Media in Education, 2002 (3)
Theoretical models of the role of visualisation in learning

Oliver, Aczel


3 See page 30: A commentary on the use of theory in the analysis of the Jape study

Journal of Interactive Media in Education, 2002 (3)


Designing For Pedagogical Flexibility – Experiences From the CANDLE Project

Aileen Earle

Abstract:
This paper examines the experience of a group of designers attempting to implement pedagogical flexibility in the design of the CANDLE system. It sketches out how flexibility is emerging as a new design criterion, but warns that the implementation of such flexibility is fraught with conflicts. After foregrounding the myth of pedagogical neutrality in system design, it examines CANDLE’s early decision to build a system around a pan-pedagogical framework and the problems inherent in such an undertaking. In particular it reviews issues such as the operationalisation of pedagogical theory, the difficulties of disaggregation of learning resources into separate objects, the epistemological conflicts in the use of static ontologies for domain representation, metadata, meaning and communities of practice, access rights and granularity. It concludes by calling for educational systems designers to consider pedagogy in all its complexity in the process of design and development.

Commentaries:
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1 This paper is my own interpretation of the challenges faced in the CANDLE project, and does not necessarily reflect the views of the whole CANDLE consortium.

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Designing For Pedagogical Flexibility – Experiences From the CANDLE Project
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1 Introduction

This paper describes some of the challenges faced by the CANDLE project team in implementing pedagogical flexibility in a courseware management and delivery system structured around a learning objects database. After a brief account of the increasing importance of flexibility in educational systems, a working conception of flexibility will be sketched out. A quick overview of conflicts and issues in the provision of this flexibility will then serve to ground the reasoning behind the decision to implement multiple pedagogies in the CANDLE system. The experiences of the designers in implementing this decision will be used to formulate questions which go to the heart of the issue to be addressed here: the difficulties and contradictions inherent in designing an educational system based on different conflicting pedagogical models. Particular attention will be paid to the problems inherent in the disaggregation and de-contextualisation of learning objects and to the epistemological difficulties of using a database to contain learning objects and static ontologies to re-assemble them into learning resources. Finally, the question of how feasible it is to implement multiple pedagogies will open up for further debate the issue of whether the foundational antinomies which set different pedagogical models apart preclude their co-existence in a single educational system.

2 Flexibility as a new design criterion

Flexibility and customisability are increasingly being positioned at the core of educational systems across the university and training sectors, a focus which lies behind the current drive for the establishment metadata standards (EPFL (ARIADNE, 1999); ADL, 2001; IMS, 2001). To illustrate, one of the Learning Objects Metadata Working Group’s stated purpose is: “to enable computer agents to automatically and dynamically compose personalized lessons for an individual learner (LOM, 2000).” In the same vein, Schatz believes that “we are on the verge of being able to provide learning customized for each specific learner at a specific time, taking into account their learning styles, experience, knowledge and learning goals” (Schatz, 2001). Collis establishes flexibility as one of the cornerstones of her ‘new didactics for university instruction’ (Collis, 1998) implemented in the TeleTOP system, whilst Moran and Myringer see the move towards flexible learning as a paradigm shift (Moran and Myringer, 1999). In the commercial sector, e-learning providers are increasingly using customisability of courseware as a major

http://ariadne.unil.ch/Metadata/ariadne_metadata_v3final1.htm
http://www.adlnet.org/
http://www.imsproject.org/
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Journal of Interactive Media in Education, 2002 (4)
selling point: Arthur Anderson employ ‘blended learning events’ to offer flexibility in their Virtual Learning Network. SmartForce, who stake a claim as the world’s largest e-learning company, describe their system as “a next generation e-Learning environment made up of over 20,000 e-Learning objects that can be assembled on-the-fly to create truly personalized, truly collaborative learning experiences based on the wants and needs of the learners.” How far this rhetoric of re-usability and customisability is applicable in existing and future educational and training environments is arguable and forms the orienting question for this paper. First, however, it is pertinent to examine the concept of flexibility itself.

Despite the increasing significance of flexibility in the design of educational systems, and the irresistible forces driving it forward, there is as yet no commonly accepted conceptualisation of flexibility. Here I will not undertake the task of constructing such a conceptualisation, but will refer the reader to work which has already been done in this area (Edwards, 1997; Edwards, Nicoll and Tait, 1999; Clarke et al., 2000) and will limit myself to sketching out the landscape of flexibility, sufficient for the purposes of explaining some of the implementation difficulties involved in CANDLE.

Moran et al note how different terms have been adopted in different contexts, including flexible learning and flexible delivery; they argue that this stems from the fact that converging trends in different countries remain to be developed into a sound theoretical construct. They cite the definition of flexible learning adopted by Mid Sweden University as a working example (Moran and Myringer, 1999):

**Flexible learning:**
- Applies to teaching and learning wherever they occur – on-campus, off-campus and cross-campus
- frees up the place, time, methods and pace of learning and teaching
- is learner-centred rather than teacher-centred
- seeks to help students become independent, lifelong learners
- changes the role of the teacher who becomes a mentor and facilitator of learning

Van den Brande (ibid) defined flexibility as “enabling learners to learn when they want (frequency, timing, duration), how they want (modes of learning), and what they want (that is, learners can define what constitutes learning to them).” Collis et al. went further and identified five dimensions of flexibility in their Telescopia project, which they further broke down into 19 different aspects (Collis, Vingerhoets and Moonen, 1997):
Designing For Pedagogical Flexibility – Experiences From the CANDLE Project

Earle

Journal of Interactive Media in Education, 2002 (4)

Page 4

- Flexibility related to time
- Flexibility related to content
- Flexibility related to entry requirements
- Flexibility related to instructional approach and resources
- Flexibility related to course delivery and logistics

Although in order to claim to be truly flexible, a system needs to integrate all the above, this paper will concentrate on the fourth dimension, flexibility related to instructional approach and resources, as this maps most closely onto the objective of this paper: an examination of the difficulty of designing for pedagogical flexibility.

3 Conflicts in the provision of flexibility

Despite the ubiquity of flexibility as a goal of educational systems designers, there is not a great deal of literature that looks at the conflicts involved in the provision of flexibility, although the literature there is suggests that this is an issue that requires critical engagement e.g. (Collis, Vingerhoets and Moonen, 1997). Johnston argues that whilst flexibility has achieved many desirable ends, it “has also been instrumental in opening opportunities for other, less desirable, developments in the system” (Johnston, 1999). She identifies four sets of issues here. The first set of issues are administrative, and revolve around issues of location, scheduling and employment. Johnston only sees these issues as problems insofar as they have not yet been systematically resolved, and she locates the site of their resolution as the organisation.

The other three sets of issues are the pedagogic, economic and philosophical implications of flexibility. The pedagogic issues will be addressed later in the paper. The economic issues include intellectual imperialism, the “MacDonaldization” of education and access inequalities. The inextricable relativism of post-modernism constitutes the main philosophical issue. Although Johnston views these three sets of issues as less tangible, she argues that they are nonetheless more contentious than the administrative challenges and she calls for them to be addressed at the level of the education system and profession.

It is in an attempt to take a small step in this direction that this paper interrogates the pedagogical issues that have arisen from the implementation of flexibility in CANDLE. It will not, therefore, address the administrative, philosophical or economic challenges. The rationale for this is not that it is logically possible to disentangle the pedagogical from the other issues for they are inextricably linked, but rather because a critical pedagogical gaze unencumbered by the wider, contextual issues is needed to get to the heart of the question of whether it is possible to implement multiple pedagogies in a single system. Accordingly, the thrust of this paper is deliberately theoretical.
4 CANDLE and its ‘pan-pedagogical’ framework

4.1 Candle System Design

CANDLE\(^1\) (Collaborative and Network Distributed Learning Environment) is a Fifth Framework project which set out “to use the Internet to improve the quality and reduce the cost of ICT teaching in Europe by using web and multimedia technology, and to enable cooperation between universities and industry in creating and reusing learning material and improving the quality of delivery” (CANDLE Consortium, 2001). At the heart of the system lies a learning objects database, or a repository of courseware, around which five main functions are envisaged. Before describing these functions, two important concepts will be sketched out as they constitute essential design features of CANDLE.

The first concept that needs to be explained is that of the learning object. Although this is another of those terms which has been variously used and variously defined (Wiley, 2000), just two main definitions will be offered here to orient the reader. The first, and possibly most widely quoted definition is taken from the above-mentioned work of the Learning Objects Metadata Working Group:

> Learning Objects are defined here as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning (LOM, ibid).

Wiley however, criticised this decision as being completely inclusive and proposed this, tighter definition of a learning object: “any digital resource that can be reused to support learning.”

The second concept to be presented is metadata. Wiley again provides us with a clear explanation\(^2\):

\(^{11}\) [http://www.candle.eu.org/](http://www.candle.eu.org/)

Metadata, literally "data about data," is descriptive information about a resource. For example, the card catalog in a public library is a collection of metadata. In the case of the card catalog, the metadata are the information stored on the cards about the Author, Title, and Publication Date of the book or resource (recording, etc.) in question. The labels on cans of soup are another example of metadata: they contain a list of Ingredients, the Name of the soup, the Production Facility where the soup was canned, etc. In both the case of the library book and the can of soup, metadata allow you to locate an item very quickly without investigating all the individual items through which you are searching.

### 4.2 CANDLE functions

![Figure 1: Functions of CANDLE system](image)

CANDLE was conceived of as an integrated learning environment into which trainers and teachers (and, in some cases, learners) could deposit and subsequently re-engineer their courseware. This would then provide a large repository of learning objects which could be searched (by tutors, learners and, ultimately, by on-the-fly course creation algorithms) and
assembled into courses which would also be delivered through CANDLE. The system would then store the data on student pathways through material etc. and use this information to suggest new ways of working through the learning objects. Finally, evaluation functions were to be built in to the system.

To make each of the intended functions of the system clearer, one example of courseware, a bank of multiple-choice questions for a first year Introduction to Psychology course, will be used as illustration. The first function of CANDLE is that of courseware re-engineering which involves the decomposition of extant courseware into separate learning objects identifiable through a series of metadata tags. So, the tutor who had developed the bank of multiple-choice questions would need to think about how she would enter this courseware into the system. She would immediately be presented with the problem of deciding whether to enter all the questions into the database as a whole, or to enter them as separate learning objects. Whichever decision she made, she would then need to describe each object with the appropriate metadata tags, indicating to potential searchers the content, form, and pedagogical purpose of each object. The second function is the search and retrieval of these learning objects and their construction into courses by learners, or by lecturers or tutors (the third function) for delivery to learners. Here, one could imagine another tutor, teaching on a different Introduction to Psychology course in another university, searching the courseware depository to find assessments she could give to her own students. In a more open setting, students would also need to seek out assessments to evaluate their own learning.

The fourth function consists of delivering this learning to the student. So, in this instance, CANDLE might allow students to take their multiple-choice exam online. The fifth and final function revolves around the evaluation of courseware and learning objects. Here the system would assist both tutors and students in evaluating the multiple-choice exam.

4.3 The myth of pedagogical neutrality

As CANDLE is in the first instance an educational system, a decision was made at the proposal stage of the project to position pedagogical issues at the heart of the system design. The question of how to do this is a more difficult issue and can be resolved in a number of ways. The first, and seemingly the simplest way of ensuring pedagogical flexibility is not to include pedagogical considerations in the system design, resulting in pedagogical neutrality – or so the argument runs. Although this is the default approach taken, including in much of the recent work in the field of learning objects (Wiley, 2000), it is based on the fallacy that unless a pedagogical
position is made explicit (whether in terms of an individual’s beliefs or the functionality of a system), it does not exist. In effect, what is usually touted as pedagogical neutrality by software vendors is merely pedagogical naivety. Two arguments will be brought into play to defend this point.

First, pedagogical beliefs are not the exclusive remit of educators – everyone holds what Bruner refers to as folk pedagogies, that is, ideas about teaching and learning which themselves have an impact on the educational strategies they employ (Bruner, 1996). Moreover, these beliefs are deeply rooted in the cultural environment which imposes epistemological values on its communities which in turn have pedagogical implications of their own. Even if – or arguably precisely because - systems designers are not able to articulate their own pedagogical stances, their beliefs will, by default, be articulated into the systems design process. More importantly, by construing pedagogical issues as outside of the remit of systems development, such designers will not be able to recognise the unintended pedagogic effects of other, apparently unrelated design decisions. To borrow from the words of Tenner, they will not be able to recognise technological decisions that “bite back” (Tenner, 1997).

The second point revolves around the nature and boundaries of pedagogy. Watkins et al. sketch out how conceptions of pedagogy have developed over the last century (Watkins and Mortimore, 1999). They note a shift in the research literature from a focus on the largely unidimensional analysis of teacher’s ‘style’ to current, complex and multi-dimensional models of pedagogy which take into account the teacher, the classroom or other context, content, epistemologies and other elements. According to such models which emphasise the interplay of all the elements, it is not logically possible to disentangle pedagogical issues from technological ones as the latter are a constituent element of the former. In other words, one cannot draw a boundary between pedagogy and technology in the way that a pedagogically naïve approach suggests you can.

### 4.4 Other methods of ensuring pedagogical soundness

In view of the logical impossibility of developing a pedagogically neutral system, what options are open to educational systems designers? One way of ensuring the pedagogical soundness of an application is to take a single, recognised pedagogical model and integrate it into the system design. There are an increasing number of suggestions of how to do this. Leflore gives potential developers sets of guidelines to implement gestalt theory, cognitive theory and constructivist theory in web-based learning materials (Leflore, 2000). Jonassen et al offer a six-step framework for
designing constructivist learning environments (Jonassen and Rohrer-Murphy, 1999). Reigeluth’s updated Instructional-Design Theories and Models book offers a wide variety of theories and suggestions on how to implement them (Reigeluth, 1999a).

This method has been used in the development of a number of significant educational systems, including the Fifth Dimension\(^\text{14}\) materials, designed around cultural-historical activity theory, and Plato\(^\text{15}\) which, along with all Integrated Learning Systems is an instantiation of the behaviourist paradigm (Underwood and Brown, 1997). The same approach has recently been taken in the development of other systems designed around learning objects (Bannan-Ritland, Dabbagh and Murphy, 2000). Whilst the implementation of a single pedagogical paradigm might be a common phenomenon, moving from learning theory to practice is never a straightforward step. The first hurdle that needs to be overcome is identifying a single appropriate theory – something which becomes increasingly problematic, the wider the context in which the systems is intended to be used becomes. The second hurdle is the operationalisation of that theory - this will later be dealt with in the section on ‘Problems implementing pedagogical flexibility.’

The second, probably more common, way to integrate pedagogy into system design moves away from using a single pedagogical model as the design orientation of the system, but still is predicated on the belief that there are a set of key pedagogical principles that should be implemented in a system. Here, a set of guidelines from an extensive base of theory and research, covering more than just one pedagogical paradigm are developed and applied in the design of the system. For example, in the design of their TeleTOP system, Collis et al draw on Norman (Norman, 1997) for a set of “key principles for good teaching and learning in higher education” which they operationalise as follows:

- Scaffold the learner’s increased self-responsibility for learning.
- Stimulate active engagement.
- Elicit articulation and reflection.
- Lecture less and give feedback more.
- Encourage more-frequent and targeted communication (Collis, 1998)."

Advice for the implementation of sound pedagogical principles in educational systems abound e.g. (Somekh and Davies, 1991; Althauser and Matuga, 1998).
A related, but slightly different approach is taken by the developers of such programmes as STAR Legacy\(^{16}\), JASPER\(^{17}\) and CSILE\(^{18}\), who could be described as working from an action research paradigm. Although much of the design rests on a wide literature base, these programmes are built on a considerable, and evolving, research base of their own – an expensive process in terms of manpower.

CANDLE initially rejected these options for two reasons\(^{19}\). The first is that the whole of the CANDLE system is built around a learning objects database; consequently a critical factor in the success of the system will be the number and kind of learning objects that populate the database (Connolly and Thorn, 1991). If no one enters any of their courseware into the system, then there will be nothing from which to develop new courses. A scenario where only learning materials which fit a given pedagogical model are allowed into the database will automatically reduce the material available to users. The reverse of the coin is that if instructors use a pedagogical paradigm in their teaching practices which does not match the paradigm legitimised by the system, then CANDLE will not be able to offer any materials of use to them. This is in essence an issue of usability, and abuts on the distance between a user’s current practice and the practice required by the system. This distance is of particular importance in an educational system where the pedagogical beliefs of an instructor are one of the key factors affecting the success or otherwise of the implementation of new educational technology (Fullan, 1992).

The second reason is more fundamental: as CANDLE is intended for use across the university, corporate and SME sectors throughout the European Union, at a time when the importance of the context of education is increasingly being recognised, it was judged that no single model or set of pedagogical guidelines would effectively fit all learning events. Certainly, there is evidence that although the different countries in Europe are facing similar challenges, there is more divergence than convergence in the responses of their education and training systems (Green, Wolf and Leney, 1999). Prescriptions are necessarily simplifications and as such cannot do justice to the complexity of the site of implementation of CANDLE. Moreover, pedagogic prescriptions involve value judgements about pedagogy, which the team did not feel able to make, being cognisant of the link between educational theory and the socio-political contexts of that theory (Walkerdine, 1998) and the impossibility of

\(^{16}\) http://www.peabody.vanderbilt.edu/ctrs/ltc/bronby/legacy.html

\(^{17}\) http://www.peabody.vanderbilt.edu/projects/funded/jasper/jasperhome.html

\(^{18}\) http://csile.nise.utoronto.ca/intro.html

\(^{19}\) Subsequently there has been a move towards supporting a more limited range of pedagogies in CANDLE, due in part to some of the issues addressed here.
developing a single, decontextualised, over-arching definition of quality (Green, 1995). The designers therefore made an early decision to design CANDLE around multiple pedagogies, so that it encompasses the traditional, instructivist approaches and the more constructivist and collaborative constituents of the increasingly prevalent student-centred learning environments (Jonassen and Land, 2000), as well as the behaviourist paradigms which underpin the competency-based frameworks which structure much of the SME and corporate training sectors.

5 Problems implementing pedagogical flexibility

Designing for this degree of pedagogical flexibility poses a whole new set of problems. This section will not attempt a full account of the pedagogical design process and all the difficulties encountered but will concentrate on a few of the more crucial problems with a view to illustrating the challenges inherent in the implementation of pedagogical flexibility.

Where CANDLE has found solutions, these will be presented, not as a neat resolution of the axiomatic conflicts which set apart the various pedagogical paradigms, but rather as subject to critical review. A discussion of the degree to which it is feasible to engineer such a resolution will be reserved for the concluding paragraphs of the paper.
Before addressing the problems, a fuller description the functions of CANDLE and their mapping onto the development life-cycle of learning objects\textsuperscript{20} (Baca, 2000\textsuperscript{21}) will help to clarify to the reader some of the problems encountered in the design of CANDLE.

As can be seen from the diagram above, CANDLE does not have in-built courseware creation facilities such as html editors or packages such as Perception\textsuperscript{22}. Instead, it is anticipated that the actual courseware, such as presentation slides, will be created outside of CANDLE and then imported into the system. Therefore, the first stage of the learning object lifecycle, the creation and multiversioning, will not be part of CANDLE.

The second stage, that of organisation, is one where “objects are automatically or manually organized into the structure of the digital information system and additional metadata for those objects may be created through registration, cataloging, and indexing processes” (Baca ibid). This links with the re-engineering function in CANDLE and is probably the area in which the most intractable of the problems have been encountered, as it constitutes the lynchpin of the whole system: its structure.

Here, courseware that already exists in the computers and files of the tutors is re-engineered. In other words, it is analysed, broken down into its constituent parts and described using metadata. Although some of this metadata tagging can be performed automatically, as is the case with file size and format, the more difficult semantic tagging of elements such as content and pedagogical stance needs to be undertaken by a subject specialist – in the case of CANDLE the instructor or trainer. Immediately one of the main constraints on the implementation of flexibility becomes apparent: there is a trade-off between the richness of the descriptions provided by the metadata and the amount of time required to tag each learning object.

Although this is a very real problem, it can be considered largely an administrative one. Other, fundamental issues deserve more extended treatment: these include the operationalisation of pedagogical theory in metadata, the implications of building a learning system around a database whose structure is provided by a static ontology, the issue of access rights and the problems of disaggregation and granularity. These issues are identified as fundamental because their solution cannot be easily found by administrative means as the problems themselves are theoretical.

\textsuperscript{20} http://www.getty.edu/research/institute/standards/intrometadata/2_articles/index.html

\textsuperscript{21} http://www.getty.edu/research/institute/standards/intrometadata/index.html.

\textsuperscript{22} http://www.qmark.com/perception/
5.1 Operationalisation of pedagogical theory in metadata

The only real criterion for assessing the usefulness of a metadata schema (a set of metadata descriptors) is the extent to which it assists in the retrieval of objects, whether it be by an instructor searching for courseware, or by a learning algorithm built into the system for delivery of that courseware. From a pedagogical perspective, this will rest on two requirements: first that the metadata should adequately and faithfully represent pedagogical theory, secondly that it should have meaning for users of the system.

The first issue is arguably the more difficult of the two as it requires an operationalisation of the whole of the domain of pedagogical theory—otherwise described as an ontology of instruction (Mizoguchi and Bourdeau, 2000). As instructional designers have long known, the operationalisation of even a single, essentially descriptive, pedagogical theory, is far from trivial (Reigeluth, 1999b). This suggests that the operationalisation of multiple theories emerging from diverse research traditions with very different sets of frames of reference, let alone of the whole domain of pedagogy, is impracticable. This question was raised, albeit in a slightly different form, by the Shared Vocabularies for Representing Pedagogical Knowledge Working Group:23 “Can pedagogical knowledge even be formalized?” The objective of this group was not to build a complete ontology of the pedagogical domain, but, less ambitiously, to develop a shared pedagogical vocabulary—a task which is still being carried forward by the IEEE Learning Technology Standards Committee.

Although this level of conceptualisation of the domain (described by Mizoguchi as a Level 1 ontology, or as "a structured collection of terms") represents the most simplistic of versions of an ontology, the problems inherent in developing it cannot be overstated (Mizoguchi, 1998). A brief reference to the work of Reigeluth, who has pulled together a wide range of pedagogical models in one volume, Instructional-Design Theories and Models (Reigeluth, 1999a), will demonstrate some of the difficulties involved. Reigeluth summarises the goals, preconditions and values of every model presented. The values include such commitments and issues as:

- "authenticity, ownership, and relevance of the learning experience for students"

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23 This working group was set up in 1996 in a workshop at the 3rd International Conference on Intelligent Tutoring Systems (ITS’96), entitled “Architectures and Methods for Designing Cost Effective and Reusable ITSs.”
• “rich social contexts and multiple perspectives for learning”, “the criticality of “what to teach” and the considerable variability of “how to teach it””

• “learning that is driven by an ill-defined or ill-structured problem (or question, case, project).”

Concepts such as authenticity, ownership, relevance, perspective, individualisation of learning, nature of the problem, focus on content emerge from these few values.

Operationalising any one of these concepts is a challenge. Moreover, even if a meaningful operationalisation of each concept were possible, there has to be a limit to the number of metadata tags that can be used to describe learning objects - we already have seven possible tags here - drawn from only two pedagogical models. The issue of selecting which concepts to choose as tags inevitably brings one back to the question of which values, and, hence, which models to privilege.

In CANDLE, after a first, unsuccessful attempt at using a literature survey to identify the factors that would constitute the pedagogical metadata, a decision was made to adopt a subset\(^24\) of the fourteen pedagogical dimensions of computer-based education (Reeves, 2000\(^25\)), in addition to some of the tags in the IMS Learning Object Meta-data scheme (IMS, 2001) as it was judged that these went a long way towards offering a workable operationalisation of the different pedagogical paradigms.\(^26\) Moreover, these dimensions (e.g. teacher role, user activity, flexibility) allow for the matching of materials, instructors and learners: just as Reeves has used the dimensions to characterise two different educational systems, it should be possible, in principle, to similarly describe different pedagogical models. Currently a project at the University of Twente is attempting to build a questionnaire based around Reeve's dimensions to help instructors and learners characterise their teaching and learning styles.

However, it is worth re-stating the first criterion for usefulness of pedagogical metadata: that it “should adequately and faithfully represent pedagogical theory.” The very process of selecting metadata tags, and building questionnaires and tools

\(^{24}\) Which tags will be dropped has still to be finalised.


\(^{25}\) See Jarret, W., Mendes, E. and Prnjat, O. (n.d.), Preliminary Metadata (WP 2 - D1 Int.): University College London. for the first draft of the metadata schema adopted in CANDLE.
around these automatically circumscribes pedagogy and will thus compromise the adequacy of representation of pedagogical theory.

This is an important point as it turns on the very nature of pedagogical theory and its boundaries - an issue which has already been touched on in the section on the myth of pedagogical neutrality. Becher, in his analysis of the cultures of disciplines has delineated two cognitive dimensions which differentiate different forms of knowledge: hard/soft (restricted/unrestricted) and pure/applied. These can be recruited to highlight the essence of the problem of operationalising pedagogical theory in metadata. He draws a parallel between the hard/soft dimension and Pantin’s distinction between the restricted and the unrestricted sciences (Pantin, 1968):

Briefly, restricted knowledge has clearly defined boundaries; the problems with which it is concerned tend to be relatively narrow and circumscribed. It focuses on quantitative issues, and tends to have a well-developed theoretical structure embracing causal propositions, generalizable findings and universal laws. It is cumulative, in that new findings tend to be linear developments of the existing state of knowledge… Unrestricted knowledge has the opposite characteristics: unclear boundaries, problems which are broad in scope and loose in definition, a relatively unspecified theoretical structure, a concern with the qualitative and particular, and a reiterative pattern of enquiry.” (Becher, 1989)

In Becher’s terms, education can be considered a soft, applied discipline. Reframing the operationalisation problem in the terms presented above, attempts to fit pedagogy into a metadata schema, although quite properly motivated by a desire for the integration of theory into practice, can be seen as endeavouring to shoe-horn what is essentially an unrestricted/soft, applied domain into a hard form. The theoretical discontinuities inherent in such a process could arguably serve to undermine the validity of any metadata schema thus developed.

One further point deserves attention. Becher notes that one of the characteristics of soft, unrestricted knowledge domains is that they have a “relatively unspecific theoretical structure”. Evidence of this is ubiquitous in the field of education, and can be found in this paper by an alert reader. Whereas the ‘hard’ sciences have a tight handle on what constitutes a hypothesis, a model, or a theory, there is no such widely accepted theoretical structure to organise pedagogical theory. Thus slippage between the usage of the various terms is commonplace and of itself makes the implementation of pedagogical theory problematic. However, attempts to impose such a theoretical model would be addressing the wrong problem, as such theoretical
structures emerge both from the nature of the subject matter of the domain itself and from the communities, with their various degrees of coherence, that form around them.

This perhaps explains in part why it soon became apparent that, in practice, although Reeves’ fourteen pedagogical dimensions did permit a description of learning objects which had the potential to link teaching and learning styles, pedagogical models and the learning objects from a systems point of view, it did not really work. The different communities constituting the CANDLE community had very different ways of conceiving of learning and teaching, and although Reeves offered them a common language with which to discuss pedagogical issues, it was not necessarily the language that they used in their practice and context.

5.2 Metadata, meaning and communities of practice

The second issue to consider is whether the metadata chosen has meaning for the users. CANDLE is a system which requires, and is being designed to facilitate, the collaboration of all users, in particular those who are submitting and using courseware. Common ground has been identified as one of the most important factors in establishing collaboration (Baker et al., 1999). It is therefore important that the concepts used in CANDLE metadata have a common and accessible meaning for all users. This does not happen automatically27. On the contrary, in different sectors, very different conceptions of pedagogy are typically held, so much so that people in the commercial sector often are uncomfortable with conceptualisations framed in pedagogical terminology (Kewell et al., 1999).

The 14 dimensions of Reeves offered the advantage of not obviously belonging to any particular pedagogical school – they can be used to describe commercial training materials as easily as university lecture notes. Moreover, unlike most pedagogical paradigms which tend to change over time and as they are adapted by subsequent researchers and authors, they offer a relatively stable conceptualisation of pedagogy. In the CANDLE project, some early, informal experience of introducing instructors from both the commercial and university sectors to Reeves, suggests that it provided a relatively straightforward way of helping people conceptualise the differences between different pedagogies. A reaction of “Finally I understand what pedagogy is all about!” was not uncommon. It is as if the instructors and trainers have been given a language to describe pedagogy.

27 This issue of an assumed common meaning was taken up by one of the reviewers.
However, as mentioned above, the construction of common meaning is essentially a social process and, as such, is not unproblematic. How possible, then, is it for metadata tags to embed common meanings in view of the fact that they are used to describe learning objects which are, by definition, de-contextualised? An analysis of different learning resources will illustrate the problem. The educational metadata section of ADL’s SCORM document includes a tag entitled ‘learning resource’, which can take such values as exercise, simulation, questionnaire or exam (ADL, 2001). Whilst at first glance these descriptors seem unproblematic, a closer examination shows that even seemingly evident educational concepts change their meaning depending on the contexts in which they are used. For example, the ASTER project found that words such as tutorial and seminar were employed to describe different learning events, depending on the discipline in which they were used. So, for example, in the humanities, the term tutorial is used to describe small group learning events, and seminars slightly larger groups. In physics, however, these larger groups would be described as lectures (ASTER, 1999).

According to Gee, who takes a situated cognition perspective, this should come as no surprise. He argues that there “is really no such thing in general as a report, an explanation, an argument, an essay... and so forth”, but that such concepts are in fact situated meanings and cannot therefore be disentangled from their contexts. They “are made understandable, not in terms of some generic genre label like article or essay, but in terms of a cultural model of the production of work in the academic fields whose situated instances these are.” (Gee, 1997) Returning to the example of the multiple choice assessment given above will further underline this point: assessment is an essentially situated practice. Frederiksen & Collins view teaching, and one of it’s key components, testing, as a complex system nested within a larger institutional system itself situated in a wider socio-political system (Frederiksen and Collins, 1989). Accordingly, the forms of assessment that are legitimated in different socio-political contexts will differ (Broadfoot, 1996): whilst multiple-choice questions will be quite acceptable as a summative assessment or ‘exam’ in one context, they would be rejected in another. The reasons for this stem from institutional beliefs about the purpose of assessment, the kind of learning that it should promote, and hence it’s very nature.

Wenger offers another illuminating perspective here. In his work on Communities of Practice he argues that meaning is located in a process of its own negotiation (Wenger, 1998). This process in turn involves the interaction of two complementary processes, namely participation and reification. Reification refers to a process of ‘objectifying’ our experience, and covers activities such as designing, naming and
encoding. However, Wenger argues, reification cannot exist apart from participation: “indeed, reification always rests on participation: what is said, represented, or otherwise brought into focus always assumes a history of participation as a context for its interpretation. In turn, participation always organizes itself around reification because it always involves artifacts, words, and concepts that allow it to proceed.” An application of these concepts to metadata suggests that tags, as reifications cannot have universal meaning, but can only make good sense within the participatory activities of a community of practice. Indeed, this is one of the reasons that issues of collaboration are being foregrounded in the design of CANDLE.

An alternative solution to this has been suggested by Recker & Wiley who recommend the addition of ‘non-authoritative’ metadata which they describe as follows: “this form of metadata captures the ‘embedding’ context of a learning object within instruction. For example, these data elements can describe how a learning object was reused, its juxtaposition to other learning objects, and its usefulness in particular instructional contexts. The metadata can also describe the community of users from which the learning object is derived (Recker and Wiley, 2001).

5.3 Epistemology, pedagogical philosophy and ontologies

This section will change the focus from pedagogical metadata to how domain knowledge (in CANDLE this is the telematics domain) is represented. Reference will be made to three of Reeves’ dimensions, Epistemology, Pedagogical Philosophy and User Activity, to highlight the epistemological conflict that has arisen from the use of a database and ontology to structure CANDLE.

In order to establish some coherence in the naming conventions employed in describing the content of learning objects, and to allow for greater flexibility in the on-the-fly delivery of courseware (the utilization phase of the lifecycle) CANDLE is in the process of developing an ontology of telematics. Ontology is a word whose meaning is contested: it has variously been described as an “explicit specification of conceptualization”, a “theory (system) of concepts/ vocabulary used as building blocks of information processing systems,” “agreements about shared conceptualizations” or a set of “concepts with definitions, hierarchical organization of them(not mandatory), relations among them (more than is-a and part-of), axioms to formalize the definitions and relations (Mizoguchi and Bourdeau, 2000).” Although modern usages of the term are moving away from hard objectivism, the academic pedigree of ontologies is firmly rooted in that tradition, signifying as it does, the study of what is. It is also worth highlighting the fact that ontologies are usually built
around entities, and that the very act of conceptualising the items that make up CANDLE as learning objects point also point to a positivist philosophical epistemology.

The tool being used to develop the telematics domain ontology is OntoEdit by AIFB, and it is worth examining it to uncover some of the assumptions on which it rests. First of all, the ontology is “constructed and maintained in a collaborative effort of domain experts, end-users and IT specialists” (AIFB, 2000). In the case of CANDLE, this consists of a group of telematics lecturers and an ontology engineer. The main elements of the ontology are the restricted set of terms of the domain lexicon with added relations (see Figure 5 for an example of a relation) and axioms (“used to model sentences that are always true”) built onto these. All of these are structured into a concept hierarchy. Once built, an ontology provides a static representation of knowledge.

Here we come up against the first real pedagogical conflict: whilst it is easy to see that an ontology resonates well with the objectivist pole of the epistemological dimension, with its emphasis on the independent existence of knowledge, it is much more difficult to see how it can be reconciled with the more constructivist pole, which eschews the whole notion of knowledge separate from knowers. For the very process of objectifying knowledge in the form of an ontology subtly shifts the epistemological balance in such a way that what is, in essence, a representation of the current beliefs of a specific group of knowers, in this case the telematics experts, takes on a far more positivist hue, which is further enhanced by the essentially rationalist character that is attributed to computer and database technology (Chandler 1990).

Figure 3: An example of relations made explicit in OntoEdit.

\[\text{http://ontoserver.aifb.uni-karlsruhe.de/ontoedit/guide/users_guide.html}\]

\[\text{The ontology does not have to be entirely static, but changes need to be made with care because of the impact they have on the system built around the ontology.}\]

\[\text{The issue of the pedagogical implications inherent in the use of a database of learning resources was debated by the author and reviewers.}\]

Journal of Interactive Media in Education, 2002 (4)
CANDLE sought to resolve this by softening the epistemological rigidity inherent in the use of an ontology through the use of two naming conventions. The first is tied to the ontology and replicates its hierarchical structure with a restricted set of nested concept descriptors. The second naming convention is not in fact a convention at all: CANDLE provides two additional metadata tags, keywords and weighting, which together allow system users to break out of the preconceived domain ontology. The keywords are entirely free and ‘unconventional’ in the most literal sense of the word: the metadata taggers are free to use whatever words they feel most appropriately describe their courseware objects. In addition, they are offered the option of weighting these objects in terms of their relevance to the more conventional ontological descriptors of the first naming convention. The courseware objects can then be organised not only according to a static ontology, but using fuzzy logic semantic search algorithms which in principle embody a much more fluid and dynamic conception of knowledge.

Like most of the solutions in this paper, this is a practical, rather than a logical solution, and as such it is only partial. It does not really solve the problem of providing students with multiple pathways through learning objects, which is essential in a truly flexible system. Whilst fuzzy logic searches might provide routes through material determined by how previous system users (either learners or tutors) have navigated the database, and ontologies might offer the ‘accredited’ steps to an understanding of a particular domain, until there is a way to link these diverse pathways with learner characteristics, the system will not be truly flexible.

### 5.4 Access Rights

Very closely linked to Reeves’ first dimension, Epistemology, are Pedagogical Philosophy and User Activity. Reeves sees the much debated conflict between instructivist and constructivist approaches to teaching and learning as a dimension of pedagogical philosophy. At one pole of the dimension lies a strict instructivist position, which holds that objectives exist apart from the learner, and are drawn from a pre-specified domain of knowledge, typically constructed by acknowledged experts. Once specified, these goals can be structured into learning hierarchies progressing from lower to higher order learning through which learners need to move sequentially. The other pole of the dimension represents a radical constructivist position, where learners construct their own knowledge so that neither content nor learner paths through that content can be pre-specified.
Here too, there is a neat dovetailing of the domain ontology and instructivism, and a corresponding conflict with constructivism. The softening of the epistemological stance referred to above is not sufficient to allow for the more generative learning activities that are axiomatic to the latter paradigm. To be true to the spirit of the constructivist pole of the Pedagogical Philosophy dimension, all users of the system should be able to contribute to the construction of knowledge, including the ontology. Thus learners, as well as acknowledged experts and tutors, should be able to enter courseware into the database and tag it as they see fit. Herein lies the second pedagogical conflict: how can you ensure the integrity of an ontology which so neatly embodies the instructivist paradigm whilst allowing learners to take part in truly generative activities, which implies that they too should be able to contribute to and construct in some meaningful way the knowledge base (including the ontology) that is represented in the system? One possible solution, which is to allow learners to contribute materials and to use free keywords to tag those materials only goes part of the way to solving the problem: until they are able to change the ontology which itself structures, and arguably constitutes the backbone of the knowledge domain, the activities they engage in will not be truly generative. This is one problem that has not been adequately solved in CANDLE; arguably it is not possible to provide for truly generative user activities in a system structured around a static ontology.

5.5 Granularity

Another aspect of the Pedagogical Philosophy dimension needs to be foregrounded: in an instructivist position, knowledge can be broken down and structured into a hierarchy, where learning typically consists of moving sequentially from the smaller, lower order blocks of material to the higher, more complicated levels of learning. This disaggregation of knowledge into separate parcels accords with the whole rhetoric of courseware re-engineering and tagging, where the smaller the object, the more usable and flexible the system.

Granularity essentially refers to the size of a learning object and is one of the key issues that the metadata tagger needs to confront. How far should she separate her learning materials into their constituent parts? Should she break down a lecture into separate PowerPoint slides or should she insert the course as a complete unit into the database? Again, the answer to this turns on pedagogical issues.

The instructivist pole of pedagogical philosophy can easily accommodate the disaggregation of learning materials into smaller parcels of knowledge – in effect, it invites it. However, not all pedagogies do. I will take a short excursion into the
literature on conceptions of learning in higher education to illustrate this. In particular I would like to refer to Marton & Dallalba’s six conceptions of learning (Marton, Dall’Alba and Beaty, 1993). Marton & Dallalba interviewed undergraduates at the Open University, and, based on these interviews, they identified six qualitatively different conceptions of learning, with different impacts on student learning. The lowest three conceptions of learning embraced a conception of learning as first the collection, then the reproduction and finally the use of ready-made pieces of knowledge. As students advanced in their studies, they moved away from this fragmented view of knowledge. Similarly Dowling (Dowling, 1998) illustrates how the presentation of knowledge as disaggregated parts contributes to a partial, fragmented conception of any domain which excludes the learner from full participation in the practices of the higher levels of academe. It is appropriate to ask whether the very fact of parcelling knowledge, which lies at the heart of the learning objects project, is contributing to such a partial conception of knowledge.

The way CANDLE has solved this problem is to give control over the issue of granularity to the contributor. This allows for courses to be entered into the database as a whole unit if the instructor feels that the disaggregation of the material is not logical or feasible.

The case of assessment in general and multiple-choice questions in particular can again be brought in here as an example of a situation in which disaggregation is not perhaps feasible and, certainly, runs counter to some pedagogical perspectives. It has long been known that assessment is one of the most powerful drivers of student learning. Broadfoot argues that “evaluation has always been, and will probably continue to be, the single most significant influence on the quality and shape of students’ educational experience and hence on their learning. Since the earliest days of mass educational provision, assessment procedures have largely governed the content of the curriculum, the way in which schools are organised, the approach to teaching and the learning priorities of students (Broadfoot, 1996).” This being the case, it becomes difficult to argue that the disaggregation of the assessment from the rest of the course is a pedagogically defensible process. Furthermore, Resnick & Resnick, arguing from a situated cognition perspective, voiced powerful criticisms of objective testing, such as the multiple-choice tests under discussion here, because of the assumptions of decomposability and decontextualisation of knowledge inherent in it. Within the learning object project, these are not merely assumptions, but constitute instead central, structuring commitments (Resnick and Resnick, 1992).
There is a related concern about granularity and instructional design in current metadata literature. There appears to be a move away from the conceptualisation of granularity as mainly an issue of the size of a learning object to a more “robust” view of it which considers the manner and extent to which a number of factors which together make up the instructional design process are combined: “…in determining the robust granularity of a learning object, one might ask, “what elements of the model, message, instructional strategy, representation, and media-logic layers are compressed within this learning object?” The larger the count, the larger the grain size of the learning object” (Wiley, Gibbons and Recker, 2000). This is an important theoretical move as it foregrounds the purposive activity that is instructional design and signals that simplistic views of teaching as the delivery of disaggregated learning objects joined together in some straightforward combination hide the very real complexity of the development of learning materials which in effect takes place in a number of interconnected layers.

### 6 Some common themes

Three main themes can be seen as emerging in the above discussion of the experiences of those involved in the design of the CANDLE system. The first is a tension between the privileging of the ontology of a small group of experts in the design of the system necessary to ensure that it offers an accepted, coherent representation of a domain and the generative requirements of the more constructivist pedagogies. The second suggests that the disaggregation of any domain, or indeed of teaching materials used in that domain, into separate pieces does violence both to conceptions of knowledge as essentially articulated and to the marked complexity of the instructional design process. The third, and possibly most important, theme to emerge is that instructional activities are essentially situated, and that de-coupling the elements which make up these activities from each other and from the context in which they occur strips them of meaning.

Although the above points have emerged in the process of designing the CANDLE system, the issues faced will apply, in varying degrees to the development of all educational systems, including libraries, portal sites and automated online courses. If these systems, including, of course those based around the technology of learning objects, are to live up to their much-touted promise, designers will have to address these, and many other pedagogical issues head-on, recognising that the easiest solutions to implement probably involve a simplification and de-contextualisation of pedagogical theory which is not easy to defend. The alternative is that the systems designed will offer simplified, water-down versions of the pedagogical process which quite simply fail.
7 Conclusion

A few of the more important pedagogical issues that have arisen as a consequence of the decision to implement multiple pedagogies in CANDLE have been briefly sketched out. There are many more which deserve attention, including the provision of multiple pedagogical templates to assist instructors in the creation of courseware from objects in the database, and the development of sequencing algorithms for the on-the-fly delivery of courses, however space does not permit their examination here. Nonetheless, it is hoped that these examples have given some flavour of the very real contradictions arising from the attempts to design a system around conflicting pedagogical models. As mentioned above, the solutions adopted in CANDLE are practical rather than logical, for in many cases the contradictions are so intractable as to obviate logical resolution. Purists might argue that in view of this it is theoretically impossible to implement multiple pedagogies in a single system, a position that deserves some credit.

An alternative perspective on this issue is possible, and probably more constructive. This would argue that like all theories and paradigms, learning theories are not perfect, but should be viewed merely as guidelines (Snellbecker, 1999). As Popper notes “All theories are trials; they are tentative hypotheses, tried out to see whether they work; and all experimental corroboration is simply the result of tests undertaken in a critical spirit, in an attempt to find out where our theories err” (Popper, 1957). An equally cogent argument can be found in Schön’s work on the reflective practitioner (Schön, 1987), which will be used as an appropriate way close this paper which set out with the aim of stimulating in some small way a necessary debate on the feasibility of implementation of true pedagogical flexibility.

“In the varied topology of professional practice, there is a high, hard ground overlooking a swamp. On the high ground, manageable problems lend themselves to solution through the application of research-based theory and technique. In the swampy lowland, messy, confusing problems defy technical solution. The irony of the situation is that the problems of the high ground tend to be relatively unimportant to individuals or society at large, however great their technical interest may be, while in the swamp lie the problems of greatest human concern. The practitioner must choose. Shall he remain on the high ground where he can solve relatively unimportant problems according to prevailing standards of rigor, or shall he descend to the swamp of important problems and nonrigorous inquiry?”
8 References


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The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory

John Cook

Abstract:

This paper examines two sides of a coin that relate to learning from dialogue. The first side of our coin relates to the role of dialogue in learning; the second side is related to the part that observations of learning dialogues can play in the design of computer-based learning environments. In order to define the scope of the paper, various complementary research question are examined. For example, one question is how and why does one learn from dialogue? A second question is how, or to what extent, can theories and studies of dialogue and interaction be exploited in a concrete way by designers of interactive media for education? Following a review of related literature I present my main argument, namely that the evolutionary approach provides a model by which research in learning, teaching and theories of interaction can jointly feed into the design process of learning technology. This is followed by an exposition of the evolutionary approach. There are three aspects to what I am terming an evolutionary approach to learning technology theory: (i) theories/models of teaching, learning and interaction, (ii) empirical observations of learning, and (iii) interactive learning environment design and implementation. The purpose of this evolutionary approach is the mapping out of not a specific theory, but how people are working towards the creation of theories. The evolutionary approach involves a constant process which slowly takes the educational technology field forward in iterative steps. In order to concretise the evolutionary approach, I examine the work of selected researchers, in the field of dialogue in learning, in the context of the identified three points of evolution. I conclude by suggesting that the evolutionary model can help designers of, and researchers into, learning technology in various important ways.

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Keywords: learning technology theory, learning through dialogue, dialogue analysis and modelling, interactive media design, meta-analysis
1 Introduction

This paper examines two issues that relate to learning from dialogue. The first issue concerns the role of dialogue in learning. The second issue pertains to the role that observations of learning dialogues can play in the design of computer-based learning environments. In this paper I argue for an evolutionary approach to examining theory. What this paper does not try to put forward is one theoretical basis for learning technologies. The purpose of the evolutionary approach presented below is, rather, to provide a primarily descriptive tool that enables us to map out how different researchers are working towards the creation of theories, i.e. a tool for meta-analysis. The evolutionary approach is a useful, if somewhat simplified, conception of the role of theory and models in learning technology development. Following the literature review presented in the next two sections, the main arguments and research questions raised in this paper are presented in section 4. In section 4 I will draw on the pre-print debate1, for an earlier version of this paper, that took place in the fourth quarter of 2001. This will enable me to lay out the main arguments and questions raised in this paper. Consequently, section 4 refers to reviews and commentaries that occurred in the online debate and the responses by myself. Given that the main concern of this paper is dialogue, and that the JiME review process encourages exploratory dialogue, it is felt that such an inclusion is appropriate. Indeed, this online review process is an excellent example of how we use language to think together (Mercer, 2000) and to clarify what it is that is being discussed. Section 5 presents the evolutionary approach, which focuses in on the relationships between the three points in what I am calling an evolutionary approach to new educational media theorising: (i) theories/models of learning, teaching and interaction (ii) empirical observations of learning, and (iii) interactive learning environment design and implementation. The evolutionary approach involves a constant process which slowly takes the field forward in iterative steps. My perspective is that no big bang or revolution is imminent with respect to theorising and modelling. Instead, I advocate cycles around the three points of evolution; this will, I suggest, bring about the gradual development of the field of learning technology, allowing us to adapt theories and models to suit our own perspectives.

2 How and why does one learn from dialogue?

Dialogue between teachers and students may be important in promoting learning (e.g. Vygotsky, 1978; Leontiev, 1975; Elsom-Cook, 1990; Lipman, 1991; Jones and Mercer, 1993; Freire, 1993; Baker, 1994; Cook, 1994; Pilkington and Mallen, 1996; Cook, 1998; Mercer, 2000; Ravenscroft and Matheson, 2002). This section attempts to examine the question: how and why does one learn from dialogue?

Students who are placed in a learning environment will usually need to interact with a teacher or learning facilitator at some point, in order to receive guidance (Elsom-Cook, 1990), feedback

http://www-jime.open.ac.uk/Reviews/get/cook/1.html?embed=-1

Journal of Interactive Media in Education, 2002 (5)
The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory

Cook

and explanations. The adaptive role of a teacher is of central importance to learning (Laurillard, 1993) because learning resources and media, such as books, journals, CD-ROMS, online databases or World Wide Web resources, etc., are rarely able to adapt to a particular group or individual's learning requirement. Students bring different histories of learning with them to a particular situation and therefore have different learning needs (Laurillard, 1993; Ramsden, 1992). Furthermore, these resources and media, typically, do not provide guidance on how they should be integrated and embedded in a coherent fashion so that learning can occur. For example, the tutor may be required to mediate between the learner and their understanding of the way in which they should use learning resources in order to meet the assessed learning outcomes of a particular programme of study. Consequently, in a learning environment, we get a complex set of relationships between how a learner thinks, i.e. cognition, how the learner interacts with teachers and peers, and the various media and resources that are available to support learning. The institution and society in which the learning takes place will also exert an influence on learning in more subtle ways.

The teacher is often more than a source of information. As was pointed out above, the teacher plays a key role in mediating a student's learning, acting as a kind of go-between or guide for the learner as they engage with the various elements of the learning environment, i.e. as they engage with other learners and tutors, learning resources and media, programme learning outcomes and assessment methods (Knight, 1995). The teacher can also help the learner to become more autonomous, to learn how to learn, and to reflect on his or her own problem-solving. The way that such explanation and guidance is provided by a teacher is usually through dialogue, either face-to-face, written or virtual, since this enables the teacher's help to be adapted and individualised to a particular student's needs. Dialogue also enables the student to verbalise and articulate his or her needs and understanding. This latter process of making knowledge explicit, and reflecting on it may itself be an interactive learning mechanism (e.g. Chi, Bassok, Lewis, Reimann and Glaser, 1989). Providing computer-based learning support that is able to acquire aspects of the role of 'teacher as mediator' is a growing area of research and development. Indeed, we are now starting to build up a rich picture of 'how' we learn from dialogue. However, in this paper what I am claiming is that, although there are many references in the literature on interactive learning mechanisms as they relate to computer-based learning (e.g. van Joolingan and de Jong, 1991; Baker, 1994; Baker and Bielaczyc, 1995), we still do not have sufficient detailed knowledge concerning the relationships between theory, empirical work and implementation of learning environments.

In contrast to the teacher as mediator perspective, Constructivism (described by Wasson, 1996) sees the major goal of education as the creation of rich sets of cognitive tools to help learners explore and interact with their environment and is closely associated with Piaget's (1971) genetic epistemology theory of cognitive development. Papert's (1980) Turtle Logo is a classic example
The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory

Cook

of a learning environment that attempts to embody cognitively relevant tools in the environment. In the case of Logo, the cognitive tools, or cognitive hooks as Papert called them, are claimed to be the graphical immediacy of geometry drawn in real-time. These cognitive hooks are intended for the young learner to use as a tool to enhance the motor skills which they have acquired from birth. Cognitive tools are generalisable tools used to engage learners in meaningful cognitive processing, knowledge construction and facilitation. For example, computer-based cognitive tools are in effect cognitive amplification tools that are part of the environment. Environments that employ cognitive tools are described as distributing cognition; they are constructivist because they actively engage learners in the creation of knowledge that reflects their comprehension and conception of the information rather than focusing on the presentation or transmission of objective knowledge. It is this last item that contrasts with the behavioural approach (see, Hartley, 1998, for a description) which would focus on content selection, sequencing, structuring and presentation.

Taking a different perspective, Jones and Mercer (1993) have argued that a theory of learning, e.g. Behaviourism or Constructivism, is not the best framework for analysing what goes on in understanding the use of media like computers in education, rather a theory and analysis of teaching-and-learning is needed. The evolutionary framework, described in this paper, takes a similar approach, drawing as it does on theory and analysis of teaching and learning. Jones and Mercer are in favour of approaches to understanding teaching and learning that have been based on Vygotsky's cultural-historical theory of human activity. For Vygotsky (1978), human mental functions appear first as inter-individual and then intra-individual, that is, by the use of socially developed tools, both technological and psychological ones. However, surprisingly little evidence has been offered to support these claims (Mercer, 2000, p. 155). For Vygotsky the unit of analysis was still the mediated action of an individual and how that individual developed. Leontiev (1975) expanded Vygotsky's cultural-historical theory to an activity theory approach to human interaction where reality consists of mediated, social, hierarchically organised, developing, internal and external, object-oriented activities. For Leontiev the unit of analysis was extended to include the collective activity, something done by the community with a motive (which need not be consciously recognised), which is composed of individual actions directed towards a goal. The individual's mediated actions could still be analysed, but there was now a social dimension which could be used to understand the individual’s actions.

Recent work with computer-based simulations (Twigger, Byard, Draper, Driver, Hartley, Hennessey, Mallen, Mohammed, O’Malley, O’Shea and Scanlon, 1991; van Joolingan and de Jong, 1991), which are used to help students acquire explanatory accounts of the real world, shows that students may fail to generate deep causal models of the behaviour under simulation because they concentrate on manipulating the simulation objects. With respect to the previously stated finding, Pilkington and Mallen (1996) make a strong case for a more Vygotskian (1978)
perspective in interaction, i.e. where the teacher mediates knowledge about the society and culture so that it can be internalised by the learner. Interestingly, this raises the following question: is this knowledge already formed and finding its way into the learner? If so, this would suggest a knowledge transmission model of education. In fact I do not mean to suggest this interpretation. In my interpretation, interaction is seen as an important component of the learning environment, helping students to recognise and resolve inconsistency, i.e. it has an adaptive mediating role. Furthermore, Pilkington and Mallen have also point out that:

…if we are to improve the quality of the interaction, then we need to understand the mechanisms by which dialogues work ... We need to know how and why, some kinds of dialogue … seem able to trigger reflective engagement and conceptual change. (Pilkington and Mallen, 1996, p. 213–214).

Recently, some researchers have suggested that dialogue with a teacher may be required if the goal is to promote reflection and conceptual change:

… self-reflection, or even reflective discussion between students may not be effective in changing beliefs and their ‘organisation’ into conception. This requires dialogue with a teacher. But … can a computer system be improved/designed to assist the reflective process, and if so, what are the requirements of its improvements? (Hartley and Ravenscroft, 1993, p. 3).

The above researchers (Hartley and Ravenscroft, 1993) go on to describe a system called SCILAB, which was designed to explore one approach, for the domain of science, to providing dialogue that encourages reflection.

Lipman (1991) has proposed an approach to learning through dialogue and has suggested that we must stipulate that education should include reasoning and judgement about knowledge. Education in the Lipman sense of the word is not ‘simply’ learning, it is a Vygotskian-like teacher-guided community of inquiry that places an emphasis on social interaction and cooperative learning. Lipman calls this the reflective model of education practice. In a community of inquiry, the teacher becomes a facilitator and the student can take a shared, active and reflective role in the development of their own understanding (Mercer, 2000, p. 161). As we will see in subsequent sections, Lipman’s work has been influential on the author’s own work in the area of promoting learning through dialogue.

Mercer (2000) extends the work of Vygotsky and introduces the term ‘interthinking’ “in order to focus attention on the joint, co-ordinated intellectual activity which people regularly accomplish using language” (Mercer, 2000, p. 16). Mercer suggests a breaking down dialogue in the following way: disputational, cumulative, and exploratory, and begins to suggest the useful features of each to learners. Indeed, Mercer has started to address the difficult question
posed at the start of this section: how and why does one learn from dialogue? Mercer talks about ways dialogue can fail as well as be successful, which seems critical to furthering our understanding of the area. For example, Mercer (2000, p. 145) points out that observational research in the classroom on children's activities in pairs and groups is 'unproductive', with more 'disputational' than the desired 'exploratory' talk happening. Mercer also reports success with interventions using his 'Talk Lessons': "children who have done the programme discuss issues in more depth and for longer … [and can] think together critically and constructively" (Mercer, 2000, p. 151).

A listening approach to the use of dialogues has been put forward in the Vicarious Learning project (e.g. see McKendree, Stenning, Mayes, Lee and Cox, 1998). This work attempts to suggest what dialogue contributes to learning that may be quite difficult to achieve in other ways. Specifically, the project was interested in exploring the benefits to learners of being able to observe others participating in dialogues. There is, however, evidence both for and against the effect of overhearing dialogues on learning (see McKendree, Good and Lee, in press). For example, Schober and Clark (1989) suggests that participants in their study who engaged in conversations with a "Director" performed better than overhearers. McKendree et al. (in press), however, counter that Schober and Clark were matching ambiguous figures in the study. What these differing results may point to is, perhaps, the suggestion that key factors in dialogue in learning are (i) the type and purpose of the dialogue (ii) the type of performance that is being measured, and (iii) the stance of the person being measured: an overhearer that takes an active stance might do just as well in a conversation, a learner that is not as active, and hence does not engage, probably would not do as well in either the overhearing or conversational modes (McKendree, J., personal communication, 30th November, 2001). What does seem certain is that the issue of exactly 'how' dialogue promotes learning is a complex one. Indeed, Mercer (2000, p. 173) admits that his "models of talk [disputational, cumulative and exploratory] are simplifications of complex reality which will need to be refined, or even replaced, as we learn more about the nature of interthinking".

To be truly equal and transformative, dialogue should not just be about content or about making appropriate use of a learning environment; it has to extend to the choice of what is to be learned, decisions about how it is to be learned and even institutional questions (Moore and Kearsley, 1996). This relates to the way that some distance learning writers talk about transac- tional distance: the perceived degree of separation during interaction between and among students and teachers. Moore and Kearsley (1996) describe transactional distance as having two components: dialogue and structure. Dialogue in this context refers to communication between students and their teacher and structure refers to the “responsiveness” of the educational plan to the individual student. One interpretation of the term ‘educational plan’ could be an orches- trated learning environment, e.g. a module that draws upon problem-based learning or an
institution that is based on a particular educational school of thought. The educational plan can thus include theory and models of learning and interaction.

Work is currently being done with applications of the Russian literary theorist Bakhtin's (1981) model of dialogic discourse to Computer Mediated Communication (e.g. Galin and Latchaw, 1998). While not really concerned with design, these early attempts at introducing Bakhtinian theory into the analysis of the uses of educational technology elucidate the concept of dialogue and see it as a broad and complex activity (as was pointed out above), which is inscribed by struggles of power and authority. However, the concept of 'control' may be more useful than that of 'power' (Mercer, 2000, p. 95) in the context of using dialogue to promote learning. Someone in a position of power may still not retain control of a situation; instead we should judge the effectiveness of dialogue for exerting control in context.

To conclude this section, I suggest that we are starting to build up a rich understanding of 'how' dialogue promotes learning, but that more work is needed to understand 'why' it promotes learning. In this section we have seen that it would appear that certain types of learning may not occur unless dialogue takes place between a tutor and learner(s). Interaction has an adaptive mediating role, helping students to recognise and resolve inconsistency. Furthermore, dialogue may take various forms: disputational, cumulative, and exploratory; but that exploratory dialogue may be more likely to lead to in-depth learning. In addition, overhearing the dialogues of other may have a positive impact on learning. To be truly equal and transformative, dialogue has to be responsive to institutional questions and educational plans. However, in order to improve our understanding of interactive learning mechanisms (i.e. 'why' dialogue causes learning) in the context of the use of new media like computers, I suggest that there is a need to link theory to the analysis of teaching-and-learning interactions.

3 System design based on studies of human communicative interaction

In this section the following question is examined: how, or to what extent, can theories and studies of dialogue and interaction be exploited in a concrete way by designers of interactive media for education? In computer-based learning there is very little work that is based on dialogue analysis. The work that has been done tends to examine students’ interactions with existing computer-based systems (e.g. Pask, 1976; Recker, 1994; Pilkington and Parker-Jones, 1996), although Anderson (e.g. Anderson and Boyle, 1985) has spent many years modelling the cognitive competencies that are taught in the domains of mathematics, computer programming, and cognitive psychology. Furthermore, Laurillard (1993, p. 102) has proposed a template for conversations that aims to map out, at a very high level of abstraction, the steps that are required for the design of interactive and adaptive media. However, Hartley (1998) has pointed out that
although the applications of technology in education are becoming more numerous, they tend to be “disparate, pragmatically oriented, and largely descriptive in the accounts they present” (Hartley, 1998, p. 20), and that we still need systematic development frameworks that are able to “link theories to methodologies and practice” (Hartley, 1998, p. 36).

The idea that we can somehow base system design on a study of dialogues is a separate concern to building systems that promote dialogue, although the former may lead to the latter. The analysis of communicative interactions may lead to important insights that guide interactive media development on a philosophical and theoretical level. Alternatively, the results may be used to suggest useful tutoring strategies that can be used in a particular learning situation. However, educational research on interactions has tended to focus on a level of analysis and description that is of limited value for the types of models and theories that we wish to construct and use as the basis of learning environment design. This level of description claim does not suppose that educational research is, or has been, carried out at the wrong level of detail. Rather, the claim is that the gap between the level at which educational research is conducted and the fine-grained detail required for learning technology approaches has, up to the present, been too great to be bridged. Support for this claim can be found in the literature:

... most of this work [educational research on interactions] is descriptive and statistical in nature. It tells us that a teacher spends 40% of his or her time responding to student-initiated activity (or whatever) but offers no help in understanding the processes and mechanisms involved. Similarly, the non-quantitative work, based on sociological and anthropological approaches, is of limited value for the types of models and theories which we wish to construct in AI and Education ... we must obviously look at education if we are to find out about educationally specific goals. It is not clear, however, whether we can derive the information we need from existing work. There is a large gap to be bridged in terms of levels of description. If the gap cannot be bridged, then it is necessary for AI and Education to include repetitions of previous research at finer levels of detail. (Elsom-Cook, 1991, p. 76–77)

Over a quarter of a century ago the designers of the WHY system attempted to formalise the Socratic method for tutoring about the rainfall processes on the basis of a study of human tutoring (Stevens, Collins and Goldin, 1982). Anderson's tutoring research (e.g. Anderson and Boyle, 1985) has been advocating and writing about the importance of looking at what students do and what tutors say as a corpus for designing teaching systems for 20 years.

More recently, the AutoTutor system has been designed to assist college students on a computer literacy course (Graesser, Wiemer-Hastings, Wiemer-Hastings, Kreuz & the Tutoring Research Group, 1999). AutoTutor uses an analysis of human tutors as the basis for its dialogue moves and discourse patterns in a curriculum script. The AutoTutor researchers attempt to use speech act theory (Austin, 1962; Searle, 1969) as the basis for their system's dialogue planning. Also,
this is the approach of the CIRCLE project in the USA, which is explicitly aimed at the goal of building dialogical learning systems, see http://www.pitt.edu/~circle/. MetaMuse (Cook, 2001) is a system that attempts to promote a Lipman-like community of inquiry (Lipman, 1991) in the context of undergraduate musical composition. MetaMuse is based on a theoretical and dialogue analysis approach (Cook, 1998) that makes use of higher-level, goal-based interaction analysis and communicative act theory. Because all situations are not ideal for speech only interactions (e.g. music), in this work Cook (1998) specifically extends the notion of a communicative act to include other acts like music and gestures (e.g. pointing).

To conclude this section, I propose that further work is needed that explores the systematic relationships between theories and models, empirical work of a fine-grained nature and the implementation of learning environments. Although some work has been done in area, I further claim that there is a need for a clearer mapping out of the problem space, both in descriptive terms and from an analytical perspective. Such a mapping exercise should enable us to draw conclusions and take the field of learning technology forward. In the next section I investigate the research questions presented in this paper in the context of the evolutionary approach.

4 Main argument and research questions

In this section I present the main arguments and research questions raised in this paper. I will draw on the pre-print debate2 for this paper that took place in the fourth quarter of 2001. So what is my argument and the questions that relate to it?

In this paper I argue for an evolutionary approach that provides a model by which research in learning, teaching and theories of interaction can jointly feed into the design process of learning technology. This model attempts to make explicit a systematic relationship between theoretical framework, analysis of empirical data and computational implementation. There are various aspects to this model, which are explored in the paper (section 5); for example, working towards design from theory or working from empirical observation to design and even working from design to theory. Below I list four research questions and then elaborate on how they fit into my argument structure.

1st research question: How and why does one learn from dialogue?

2nd research question: How, or to what extent, can studies of dialogue and interaction be exploited in a concrete way by designers of interactive media in education?

3rd research question: How do we design situations, intended to promote learning from dialogue, in a human-computer context?

http://www-jime.open.ac.uk/Reviews/get/cook/1.html/embed=-1
4th research question: How do the above 3 questions relate to each other?

In summary, I argue as follows:

Point 1. Although dialogue is important in promoting learning, especially when we take into account the recent interest in Internet-based Computer Mediated Communication (CMC), we do not have available to us the precise details of the mechanisms of interactive learning for all domains.

Supporting evidence for point 1. Essentially I am claiming that we do not have detailed answers to research question 1 in all of the various disciplines. Some excellent work is progressing in certain areas; e.g. see Section 2 of this paper.

Point 2. This problem (noted in point 1) also arises for the case of human-computer educational dialogues, yet here we have the added problem that we need to know how to design new interactive education media (e.g. pedagogical agents, CMC) that are capable of sustaining such dialogues. So there is an added question (research question 3): How do we design situations, intended to promote learning from dialogue, in a human-computer context?

Point 3. Two possible approaches to designing new education media are ‘theory-intuition to design-evaluate-and-refine’, and from ‘human-teacher-student-dialogues and theory to design-evaluate-and-refine’. In my own work, I have chosen to focus on the second approach, because, given that many of disciplines have not yet been adequately formalised, our intuitions can not be sufficiently informed. It is therefore reasonable to begin from what human experts do, to modulate this knowledge to system design and refine the system on the basis of evaluation (in section 5 I partially addresses research question 2 and 3 for a limited part of musical learning).

Counter argument3 to point 3 by Reviewer 1 (Anon). The first approach to design, mentioned above in point 3, is the most common. Indeed, Reviewer 1 points out that theories, which typically have little specific to say about process, seem at the moment to be distant from design. The typical approach being one of going for design based on intuition and experience, then running a trial and then refining techniques on the basis of evaluative feedback from the trials; there is, generally speaking, only a nod in the direction of theory and the problems of practice.

Cook’s response to the above counter argument by Reviewer1. I accept that, in the cut and thrust of designing educational systems for practical use, theory is often overlooked or marginalised as excess baggage. For example, look at the recent techno-centered developments with reusable learning objects (IMS <http://www imsproject org/metadata/>, IEEE LOM <http:www-jime.open.ac.uk/Reviews/get/cook/1/1.html

Journal of Interactive Media in Education, 2002 (5)
http://ltsc.ieee.org/wg12/>, etc.). However, what I propose is an approach to research in this area, which is really a sensible research framework in my view. Consequently, I present a simple model that attempts to make explicit a systematic relationship between theoretical framework, analysis of empirical data and computational implementation. The following question then arises: Why bother? There are two good answers to this question. Firstly, we can not assume that we know how to design systems that match to the cognitive capacities of users, or indeed that mesh smoothly with the social and organisational settings in which the system will be used. Many existing IT systems have not been successful because these factors have not been incorporated in their design (Landauer, 1995). More research is needed that attempts to systematically solve the previously mentioned problems, and that then feeds this knowledge back into the evaluation and design of more effective IT systems and products (Norman, 1986, 1996; Long, 1996). The second answer to the ‘why bother?’ question starts with a further question: what were the main research concerns in 1991? The Elsom-Cook quote (section 3) highlights the claim that, ten years ago, one (possibly specialised) view was that a lot of the work needed redoing for AI in Education purposes. The, implicit, idea being that once this fundamental work had been done, we could then speed up the production of educational systems by drawing on a stronger empirical and theoretical foundation (think of Van Lehn’s work on the Andes system (e.g. Gertner and VanLehn, 2000) based around the self-explanation empirical work of Chi and team (e.g. Chi, Bassok, Lewis, Reimann and Glaser, 1989) and indeed by Van Lehn himself). Ten years on from the Elsom-Cook quote I would claim that this fine-grained work still needs to be conducted in some domains. (But perhaps not all? Have the problems been cracked in science and mathematics?).

Point 4. Further counter argument4 by Reviewer 1: Can current observations help if the educational approach with the computer is innovative and is to disturb the (current) educational process? I take this to mean that once we have observed human tutors, which may in itself disturb what is being observed, and have used the findings to build a wonderful new system or to inform how we organise CMC, how valid are observations of this new computer-based approach when this novel approach is essentially disturbing the status quo, i.e. changing the previous pattern of educational practice; see also Draper and Anderson (1991) for a discussion on these issues.

Cook’s initial response: This is an interesting point, here is a brief response. I have done some action research into introducing a Lipman-style community of inquiry (which entailed opportunities for vicarious learning) to multimedia undergraduates (see Boyle & Cook, 2001; Cook, Leathwood and Oriogun, 2002). The innovation was embedded into CMC work and assessed, and according to student ratings was a success for 2 years running. I personally viewed it a success but have not analysed the dialogues in any detail (although students were given marks for successfully conducting an argument, i.e. for content and context of their postings). I see

\[http://www-jime.open.ac.uk/Reviews/get/cook/1/1.html\]

Journal of Interactive Media in Education, 2002 (5)
such innovation as the life-blood of the reflective practitioner, but am aware of the sensitivity that has to be applied when introducing innovation. I recently described, in a talk (LTSN Information and Computer Science 2001 conference) my approach to facilitating a community of inquiry and vicarious learning (i.e. small group, online, assessed debates which were open for all to students to observe or even participate in; a form of peer learning). At the talk one colleague was very surprised that I allowed such openness, commenting that her students insisted on privacy for assessed group work. Lachlan MacKinnon (from Heriot-Watt, who was associated with some of the early vicarious learning work) was chairing the session and supported me by making it clear that, ideally, students should to be exposed to dialogues, they had to experience them in order for the vicarious learning effect to work. My further response was that my approach was based on a theory that has been used in practice. Lipman’s (1991) approach is used world-wide to teach philosophy to children, I have used it with a music educator in the domain of music composition education (Morgan and Cook, in press) and the students involved in the second year of multimedia module innovation gave the online critical debate a 70% satisfaction rating (Cook, Leathwood and Oriogun, 2002).

The point is that the introduction of new interactive media in education can create more problems than it solves. However, if handled with care (e.g. as action research) then it can provide new opportunities. In the second year of my innovation, I introduced online critical debate to 123 students from a wide variety of educational backgrounds. I feel strongly that this is something that I could not have achieved so effectively by conventional means and the limited resources that pervade the post-1992 universities in the UK. Going back to the evolutionary approach, I started from theory and went to design of a CMC environment, action research on the practice revealed success and problems which fed back into redesigns of the CMC approach.

Point 5. Regarding research question 4, how do research questions 1 2 and 3 relate to one another? I hope the above discussion has shed light on this question. My own view is that we need to examine all three questions in a systematic way. These questions should be examined in the context of the three aspects of the evolutionary approach: theory, empirical work (or indeed other research methods) and computational implementation; and hence made the object of deep intellectual debate. In the next section I provide a detailed account of the evolutionary approach and illustrate it with examples from three researchers.

5 Evolutionary approach to theory

In this section I present an evolutionary approach to analysing the role of theory/models, empirical work and technology in learning. Specifically, the purpose of this evolutionary approach is the mapping out of not a specific theory, but a mapping out of how different researchers are working towards the creation of theories. As Mercer (2000, p. 73) points out:
The creation of human knowledge is not simply the accumulation of facts, skills and ways of making sense of experience. It is also a process of evolution, in which alternative explanations, proposals and solutions compete for survival.

The point being that in the evolutionary approach there is a requirement to be transparent about the theory and models in use. This requirement, in itself, may not communicate well from one discipline to another, as words have different meanings in different disciplines; indeed, words have different meanings within a discipline. The only solution to this problem is, in my view, careful and continuing dialogue between all stakeholders. The evolutionary approach contains the following three components:

1. **Theories/models of learning, teaching and interaction.** A theory or model can be used as a means for understanding and predicting some aspect of an educational situation. Theories are not the same as models. A theory can possess an explanatory power and can consist of a set of general assumptions and laws … that are not themselves intended to be directly (in)validated (for that, the theory must engender a model). Theories are foundational elements of paradigms, along with shared problems and methods (Kuhn, 1962) (Baker, 2000).

Thus, a theory of cooperative problem-solving should predict what forms of cooperation should exist, and ideally what interactive learning processes they trigger. A model of an educational process, with its attendant theory, can be used to form the basis for the design of a computer tool for education (Baker, 2000). What is meant by a ‘theory’ or ‘model’ can vary across the different disciplines. For example, they may manifest themselves as descriptive, explanatory, analytical, quantitative, symbolic, analogue, or other approaches. I will leave it to others in this Special Issue of JiME to debate these issues.

2. **Empirical observations of learning.** This may involve a variety of research methods used to observe human-human interactions or human-computer-based learning environment interactions (some researchers may observe computer-computer dialogues). For example, the phenomenon predicted by a model of cooperative problem-solving may be tested by quasi-experimental method. On the other hand, other research approaches, e.g. grounded theory, may come in at this point from the perspective of immersion and experience of the educational interactions, deferring theorising until data is analysed (theorising may be deferred indefinitely in some cases).

3. **Interactive learning environment design and implementations.** This is the building of a computer-based educational artefact. An example of a model-based approach being linked to
the artefact is provided by Baker and Lund (1997), who describe a model of task-oriented dialogue that forms the basis of design and implementation of tools for computer-mediated communication between learners and teachers in a computer-supported collaborative learning environment.

If we accept Baker’s (2000) argument that models are not, by their nature, necessarily computational models of individual cognition, this opens up a wide range of possible ways in which theories and models can form the bases of design of educational artefacts. As Baker (2000) also points out, what is required of such an endeavour is that the specific nature of the relations between theory, model, corpus (i.e. transcriptions of interaction data), and design of learning environments be made as explicit as possible as legitimate objects of scientific discussion and as means of generalising findings towards re-design. The author’s previous work (Cook, 1998; Cook, 2001) describes precisely such a principled relation for the case of a pedagogical agent for learning musical composition. This previous work by the author, which is summarised in Figure 1, explored the systematic relationships involved when moving from theory, i.e. the Knowledge Mentoring framework at the top of Figure 1, to an analysis of corpus data (Cook, 1998).

Briefly, the Knowledge Mentoring framework is a theoretical framework of mentoring which includes the following sub-components: (i) categories of goals drawn from theory (Vygotsky and Lipman, who were described above), (ii) a three level analysis framework of goals, subgoals and communicative acts, (iii) a theoretical model of pedagogical agents (values, wants, commitment, intention and an action cycle). The categories and the three level framework were then used to guide the analysis of empirical data and to thus generate various results.
An analysis of corpus data (Cook, 1998), of human teacher-learner interactions, showed that in the domain of musical composition, creative problem-solving interactions (which I call problem-finding) had the underlying sub-goals of probing, target, clarify and give reasons. Specifically, the results of my empirical work indicated that the two most frequently used teaching interventions related to creative problem-finding were as follows. First was critical probing, where focused questions were used by a teacher, questions which were based on observations of a student’s musical phrase; these questions had the intention of either helping the learner find an interesting problem to work on, or of prompting the learner to elaborate on their creative intention. Second was target monitoring or reflection level (in the learner); this was open-ended questioning that involved the teacher’s attempts to elicit verbal self-explanations from the learner about their own attempts at specifying an interesting problem. Learner problem-finding involved ‘critical clarification’ (elaboration and refinement of some point may be requested or given because (i) a previous attempt was unclear or (ii) a response was required) and ‘critical give reasons’ (any interaction that involves the giving of criteria as a reason).

Figure 1 also shows that the empirical findings (Cook, 1998) were in turn used in the design of interactive system that is able promote learning through dialogue, i.e. MetaMuse in the bottom right of Figure 1. The dotted line in Figure 1 means that no explicit link exists between the two evolutionary points for the work under examination (but see below). Figure 2 gives an example of a MetaMuse interaction with a learner. The most recent dialogue output from MetaMuse is shown at the top of Figure 2 in the ‘MetaMuse output’ box.
The learner has already selected an option from the Respond menu, which is blanked out in Figure 2 because MetaMuse has now put up the Interaction Box in order to enable the learner to respond. The learner has selected the top button from the Interaction Box (shown in the middle of Figure 2): “Make a statement about your phrase”, i.e. musical phrase, which leads MetaMuse to put up a dialogue box for the learner to enter an “assertion”, which should provide clarification about what was intended with the octave leaps (the learner’s list in the MetaMuse contains values that are all multiples of 12, and which are hence all octaves in the musical scheme used in MetaMuse).

I have argued (Cook, 2001) that the use of human expertise, when modulated, rather than transferred, to the computational medium, is an appropriate starting point for interactive media design; this argument is represented on the bottom line of Figure 1 (see also point 3 in section 4). By modulated I refer to the ability to pass from one state into another using a logical progression. In my own work the initial state was the corpus of data that resulted from the observation of human learning-teaching interactions. The target state was the incorporation of this data into a pedagogical agent design. A logical progression, i.e. the modulation, in my context involved the use of dialogue analysis and modelling techniques to enable aspects of
interaction data to be converted into a computational model that was used in a learning support system. I was not attempting to transfer human expertise, which would involve attempts to computationally simulate, in a cognitive science sense, the human teacher. Instead, my goal was to modulate interaction data into the design of a computer-based pedagogical agent.

I now provide further explanation of the above argument. The issue of taking descriptive basis for system design, i.e. basing design on a study of dialogue and interaction, can be restated as the question: What is the nature of the argumentative link between the analysis-description of what a human teachers and learners did and the design of a system? The relation can not be one of direct transfer of expertise, for a number of reasons. On the purely dialogue side, you have open-ended spoken dialogue versus constrained human-computer dialogue. And then, artificial agents are not meant to be copies of human ones. The interaction analysis framework and the study described in Cook (1998, 2001) are part of a pedagogical agent design approach that aims to make practical use of empirical research in pedagogical agent development. I have argued, therefore, that because very few studies have examined how to develop an artificial agent in this way, i.e. to systematically link empirical data to agent design, the best starting point was to look at what human teachers and learners did, and to then implement descriptive models of that (in my case state transition networks). Refinements to the agent and to guiding theories or frameworks, e.g. the Knowledge Mentoring framework, can then take place on the basis of what happens in the real target dialogue environment when students use the system. Any refinement would thus take place as a result of formative evaluations.

Although the users in an initial evaluation of MetaMuse (Cook, 2000) reacted favourably, the initial evaluation of the pedagogical agent did not give much insight into the following question: what are the interactive means by which learning agents engage in cooperative, creative problem-solving? Consequently, I addressed this question by a detailed analysis of a transcribed corpus of the face-to-face interactions that took place between cooperating students when engaged with the pedagogical agent MetaMuse, i.e. I followed the link from empirical work up to theory (Figure 1). Specifically, the analysis results were used to clarify, at a fine level of granularity, a model of cooperative, creative learning. I proposed that, in cooperative dialogue, the interactions will not focus on ‘winning the argument’ or ‘persuading your partner’, it will involve an acceptance by both participants that they will attempt to ‘find and refine’ a problem specification; where a problem specification is a description of a problem that is interesting or novel. In this empirical work (Cook, 2000) interaction relating to cooperative, creative problem-solving was seen to revolve around a interactive learning process of find-predict-explain-refine; this process was achieved by the interacting learning agents (where an agent can be human or computer-based) primarily through the adoption of the goals ‘probing, target, clarify and give reasons’.
Writing the redraft of this paper has prompted me to re-examine my corpus in order to address, from my perspective, the question ‘how exactly does the process of find-predict-explain-refine work?’ In fact I am trying to make the dotted line in Figure 1 solid (in that I am developing a theoretical model which I hope will give rise to a redesign of the computer-based agent). Cooperative-find-weak was observed in the corpus (Cook, 2000) and was defined as initial experimentation by the pairs in the study (who interacted with each other and MetaMuse). Cooperative-find is where the pairs were starting to come up with some novel idea; find-clarify was an elaboration of that creative intention. Below is an example from one of the sessions in which cooperative-find was identified; cooperative-find was identified on a total of 18 occasions in 6 sessions (indeed MetaMuse was designed to promote such interactions).

24: S: Right. Yeah. Would be [ADDS 4 TO LIST] one minor a third up from that original phrase, ah.
25: J: Right you got it.
26: S: Then it would be back [ADDS 0 TO LIST] again so I know what that’s going to sound like because I’m a musician myself, but are you, do you know what it’s going to sound like?
27: T: No not really. I have a rough idea but it’s very rough I think. [PAUSE] Maybe we can you can help me? [LAUGHTER FROM BOTH T AND S] See whether we hit or miss?
28: S: OK, well I’ll put that what I’m going to do is [INSERTS A 1 AFTER FIRST 0]
29: T: Interesting.

The above extract shows the usual management of the interactions by the participants in order to facilitate cooperation; e.g. at turn 25 subject J confirms involvement in the dialogue presented in the previous turn by S. At turn 26 S takes on the role of a tutor with the adoption of a ‘target’ goal, i.e. the utterance “do you know what it’s going to sound like?” is an attempt to elicit a verbal self-explanations from T about their joint attempts at specifying an interesting problem. At turn 27 T admits to having a “rough idea” of what the musical phrase that they are jointly composing will sound like. There is an imbalance in this dialogue in that S is taking the lead, but T seems happy to cooperate, explore, explain and learn. I would claim that MetaMuse has successfully structured the interactions between the two learners in order to set up the right conditions for a creative community of inquiry, where the learners take on the role of asking open-ended questions like the ‘target’ question at turn 26. Indeed, I would make the tentative claim that the reason ‘why’ this exploratory dialogue promotes problem-finding is because one of the participants has been encouraged by MetaMuse to take on the role of a tutor who asks open questions; i.e. *the type of questions that are asked is important*. An example of balanced problem-finding interactions, from the same corpus but from a different session, is shown below.

Journal of Interactive Media in Education, 2002 (5)
152: JA: But a test wasn’t it, because up until this stage we’ve just been playing around to see what’s been going on that’s …
153: C: yeah if it was, if it was going to be creative the music doesn’t sound unpleasant then, emphasise the first note of each phrase, possibly to make it more interesting.
154: JA: A reflection on how we would improve it from here or emm
155: C: It assumes it’s creative in the first place I mean.
156: JA: Yes, so could improve, yeah move on or do you want to go back and play around with that one a bit more.
157: JA: [TYPES: "(EMPHASIS) COULD IMPROVE THE PHRASE"; CLICKS ON RETURN]

The cooperative problem-finding that occurs in the above dialogue extract is indicated by the fact that there is a tendency for each participant to finish off the other participant’s sentence. The extract above shows the very first moment at which JA and C decide jointly to move on from the current attempt at creating a musical phrase, which JA at turn 152 describes as a “test” (i.e. cooperative-find-weak), and to now have a real attempt at creativity. JA’s comment at turn 152 seems to prompt C to suggest that they might “emphasise the first note of each phrase” (turn 153) and that this would possibly make the phrase “more interesting”. At turns 154 and 155 we get some joint ‘find-clarification’ on C’s proposal in the context of the task they have been set. At turn 156 JA accepts this new direction and at turn 157 JA types in the creative intention into MetaMuse. In future work I intend to re-examine more of the corpus in order to pin down more precisely the exact mechanisms involved in the identified process of find-predict-explain-refine. Interestingly, tutors that encourage an open style of interactive dialogue, like that promoted by MetaMuse, have been found to be just as effective as when tutors give explanations and feedback (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001). One implication may be that pedagogical agents may not always need to have built within them a large knowledge-base, or indeed, complex user models. Instead, pedagogical agents, like MetaMuse, that structure interactions and promote an open style of questioning may be perfectly able to promote deep learning.

Baker has considered different issues with respect to the evolutionary approach. His relevant work is summarised in Figure 3. Unlike Cook, Baker (2000) argues that there should not be any modulation in the case of Computer Supported Collaborative Learning; rather, a corpus is a means of validating a model or theory of interaction and learning (i.e. theories of argumentation). Baker does not attempt to move from empirical work and modulate the findings into the design of a system (this is shown by the dotted line at the bottom of Figure 3). Instead, for Baker the problem is then shifted to that of understanding how exactly (quasi-)formal models of interaction and theories of cooperative learning can ‘give rise to’ computer-based learning
support. That is to say, Baker starts with theories and models, has then run sessions to validate or disprove the model or theory, and has then used the revised theory or model to influence the implementation of computer-based learning support (the ‘gives rise to’ link in Figure 3). In fact the dotted lines in the descriptive diagrams, Figures 1 and 3, provide a limited analytical facility, in that we can see what aspect of the evolutionary approach is being omitted by a researcher. This can in turn highlight areas for future work.

Theories and Models of interaction

*Figure 3: Baker’s focus in the context of the evolutionary approach*

Ravenscroft and Pilkington (2000) have used the evolutionary approach, shown in Figure 4, to develop a collaborative, computer-based framework for argumentation that addresses problems of conceptual change in science (Twigger et al., 1991), which was described above. The interaction was designed as a prescriptive ‘dialogue game’ (e.g. Levin and Moore, 1997) which modelled features of a tutorial process. Within the developed scheme the learner adopts the role of an explainer whilst the system plays a facilitating role, and these participants collaborate to develop a shared explanatory model of a qualitative, causal domain. A prototype system CoLLeGE (Computer based Lab for Language Games in Education) implements this theoretical framework and currently operates as a dialogue modelling ‘workbench’ for demonstrating, investigating and developing the approach. Furthermore, an empirical study was conducted which showed that performing this dialogue game supported the dialogue process in ways which stimulated students to revise and refine their beliefs, leading to conceptual change and development in science (Hartley and Ravenscroft, 1999). The empirical work was reused to improve the redesign of the workbench (the bottom line in Figure 4).
The above examples have shown how the evolutionary approach is essentially one of iterative design in slow motion. The researchers described in this section have started from theory and models and proceeded to test them out by going either way around the evolutionary cycle. Not all researchers have completed a full cycle, but they may do so in the future. The following questions now arise:

- Are the approaches presented above complementary, or do they reflect inherently different value systems or approaches?
- Can one approach be used to extend the other? For example, do the gaps in the options that were highlighted above illustrate or warrant further investigation?

With respect to the first question, I would claim that very little work has been done on how to modulate data form studies to computer-based learning environment design. This is a contentious claim and I accept that there have been some notable exceptions (see section 3). Furthermore, although it is primarily a descriptive model, the evolutionary approach can help to explain the contributions of different studies and illustrate what further work needs to be done. Consequently, I suggest that it is possible to use my model – particularly the idea of gaps – to shape future work. For example, the author has, more recently, investigated educational dialogues form the opposite direction to Baker. In this recent work (Cook, 2000 – also discussed above) I describe how MetaMuse was designed to ‘structure interactions’ in such a way that would, it was predicted, facilitate creative problem-solving dialogues, i.e. I was starting from the bottom rights of the evolutionary model. I then used MetaMuse to generate interaction data (the gap in Baker's work). Thus, in this recent work I have travelled clock-wise around the evolutionary framework. The computer-based agent, MetaMuse, gave rise to dialogues in an
empirical study, which when analysed gave rise to a fine-grained model of interaction and cooperative learning (Cook, 2000). This model may contribute to future theorising in the area of communities of cooperative, creative learning. Indeed, earlier in this section I took the first step in this direction by re-examining the Cook (2000) corpus in an attempt to build up a descriptive, theoretical model of the find-predict-explain-refine interactive learning mechanism. Once I have fully articulated this model, I hope to incorporate it into a redesign of MetaMuse (thus making the dotted line in Figure 1 solid).

In this section I have illustrated that the evolutionary framework can be helpful in identifying the theoretical work, and attendant dialogue analysis approach, that is being undertaken in the area of interactive media for education development. Furthermore, the evolutionary approach appears to have a high level of descriptive generality due to its simplicity and some potential as an analytical tool.

6 Conclusions

In this paper I have examined the role of dialogue in computer-based learning and observing learning. I have proposed that in order to improve our understanding of learning in the context of the use of new media in education, we need to link theory and models to the analysis of teaching-and-learning. Furthermore, I have posited that certain types of learning may not occur unless dialogue takes place between a tutor and learner(s). Interaction has an adaptive mediating role, helping students to recognise and resolve inconsistency. Explaining one’s problem-solving strategy or overhearing the dialogues of others may have a positive impact on learning. Furthermore, dialogue may take various forms: disputational, cumulative, and exploratory; however, exploratory dialogue may be more likely to lead to in-depth learning. Indeed, in the previous section I have made the tentative claim that the reason ‘why’ some exploratory dialogues may promote cooperative learning is because one of the participants has been prepared to take on the role of a tutor who asks open questions; i.e. the type of questions that are asked is important. Finally, in this paper I have presented a three-part evolutionary approach to investigating theories and models of interaction and learning.

First, let me concede that in this paper I have not been able to provide conclusive answers to some of the research questions posed in section 4 (the themes are, as Reviewer 1 points out, big ones). Indeed, it was never my intention to do this. Let me explain my position by drawing a parallel with a position highlighted in a recent journal editorial piece called ‘Introduction to this Special Issue on New Agendas for Human-Computer Interaction’. In this Kellogg, Lewis and Polson (2000) highlight some concerns in their field. Specifically, Kellogg et al. draw attention to researchers in the field who are strongly critical of prevailing research practice in HCI … [that places a] disproportionate emphasis on radical innovation rather than evolutionary improvement in the field.
In a similar vein to the above critique of Human-Computer Interaction, I am suggesting that attempts to provide a 'big' or unified theory to underpin learning technology development may be premature (even if they are valuable additions to the debate). Furthermore, I would argue that the overemphasis on technical solutions like those pervading the field of reusable learning objects must be replaced by hard work on a deep intellectual agenda. In this paper I have tried to draw on my own work for the past 10 years to propose an evolutionary approach that challenges new learning media researchers to think systematically about the very complex business of placing theories and models of learning, teaching and interaction at the centre of their activities. If I succeed in provoking thought and reaction, as I appear to have from the reviewers of this paper, then I will feel that the proposal takes us one step further on our "field's" evolution.

I conclude by suggesting that the evolutionary approach can 'potentially' help designers of, and researchers into, learning technology in three important ways (but accept that a lot more work is needed to justify this claim). First, it allows them to examine and compare the theories and models that are available for the design or research task in hand. For example, in the previous section I have demonstrated how the evolutionary approach can be used to compare different research projects. This should in turn enable a critical debate to take place, within the learning technology community, about what the different theoretical models and design approaches have to offer. Second, the evolutionary approach enables researchers and designers to develop models and theories that are appropriate to their own context, particularly in terms of educational objectives and the level of granularity. The use of interaction analysis is particularly useful in obtaining fine-grained data that can be used as the basis for the design of new forms of interactive media (i.e. modulated) or to verify a theory. Granularity is an issue for reuse of learning materials. For an approach to be valuable it is necessary for the learning objects themselves to be “identifiable, discoverable and useful at the smallest appropriate level of granularity” (MEG, 2001). A big problem with a lot of the current reusable objects research and development is that the theoretic basis from a pedagogical perspective is very rudimentary, with much of the development being on the technical level. The evolutionary approach could be used in helping to clarify the theoretical base for learning object reuse. Furthermore, if a fine-grained level of detail is not appropriate for a particular project then the evolutionary model can be used to zoom out, as it were, and take a higher level view of what is happening in terms of the three evolutionary points; for example, to examine the political and social aspects of learning. The third advantage of the evolutionary model is that it helps us to assess the ways in which different researchers are taking the area of learning technology theorising and modelling forward. In my view this last advantage is a key point that should lead to evolutionary, and not revolutionary, theorising in the evolving ‘discipline’ of learning technology.
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The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory


The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory

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Educational Technology: The Influence of Theory

Kim Issroff, Eileen Scanlon

Abstract:

In this paper we explore the role of theories in current practice in educational technology. We review a range of writings from the past 30 years on the nature of learning technology research. We discuss influences on learning technologies from the related fields of Artificial Intelligence in Education (AIED) and Human-Computer Interaction (HCI). We identify two groups of theories which have been used. The first group are related to principled decisions about the design of learning materials. The second group influence the ways in which we frame our research on learning. Research in learning technologies in the future will need to draw on both groups of theories. In this paper, we draw on our own experiences as educational technologists and the purpose of the paper is to encourage other educational technologists to join with us in reflecting on their own use of theories.

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1 Introduction

The OU has had an Institute of Educational Technology (http://iet.open.ac.uk/) since its inception, with the aim of carrying out research and supporting the use of technology in courses at the university. Increasingly, other universities are setting up similar departments with similar aims. The foundation of the Higher Education Research and Development Unit (now the Department of Education and Professional Development) at University College London in 1996 is an example of the current growth of interest in educational technology in traditional higher education institutions. Other examples include the Institute for Learning and Research Technology at Bristol University, and the Educational Technology Services at the University of Warwick. There has been a proliferation of groups and departments which to support effective teaching and learning within higher education, many with an emphasis on the use of technology and this had led to an enormous increase in the number of people engaged in the practice of educational technology. Therefore we consider it to be timely to examine how influences from the constituent disciplines have guided practice in educational technology. In particular we will look here at the idea of educational technology as applied educational science and how theories in these disciplines are used. We look here at influences from education, artificial intelligence in education and human computer interaction.

2 History of Educational Technology

Educational technology is a multidisciplinary activity that is currently enjoying a period of growth. The notion of educational technology as an applied educational science was given a great boost by the foundation of the Institute of Educational Technology in the early days of the development of the United Kingdom Open University in 1969. Its importance was recognised in the speech of the Open University’s (OU) first chancellor Lord Crowther at the OU inauguration on the 23 July 1969.

The world is caught in a communications revolution, the effects of which will go beyond those of the industrial revolution of two centuries ago. Then the great advance was the invention of machines to multiply the potency of men’s muscles. Now the great new advance is the invention of machines to multiply the potency of men’s minds. As the steam engine was to the first revolution, so the computer is to the second. It has been said that the addiction of the traditional university to the lecture room is a sign of its inability to adjust to the development of the printing press. That of course is unjust. But at least no such reproach will be levelled at the Open University in the communications revolution. Every new
form of human communication will be examined to see how it can be used to raise and broaden the level of human understanding. There is no restriction on techniques.

This extract is interesting as it accurately predicts the current concerns of educational technologists from the practical (techniques that work) to the importance of the communications revolution, the role of the computer, an examination of new media, and the consideration of the implications of communication for conventional as well as distance institutions of higher education.

According to Derek Rowntree (1979), one of the early OU innovators, educational technology is concerned with the design and evaluation of curricula and learning experiences and with the problems of implementing and renovating them.

O’Shea and Self in the early eighties pointed out that educational technology was no longer solely concerned with devices or equipment but was a branch of the behavioural sciences, which currently carries no commitment to any particular theory of learning. They continue:

Educational technologists would not therefore consider the computer as just another piece of equipment. If educational technology is concerned with thinking carefully about teaching and learning, then a computer has a contribution to make irrespective of its use as a means of implementation, for the design of computer based learning environments gives us a new perspective on the nature of teaching and learning and indeed on general educational objectives. O’Shea and Self (1983), p. 59

In this paper we wish to explore how this new perspective might be developed. As practitioners of educational technology, our work involves the design, implementation and evaluation of examples of learning systems in higher education. Our work is in many ways entirely practical, requiring us to make decisions based on the potential of contemporary technologies. However, we find that the design and evaluation of teaching material, as O’Shea and Self point out, requires us to draw on research in a variety of disciplines, especially education. It also gives us the opportunity of designing experiments to test out designs based on theories and to help us explain the factors which influence the students’ learning. Our aim as educational technologists is to improve the quality of students’ learning.

It is interesting to note that some other commentators give theory less of a central
role. For example, the 1996 Handbook of Educational Technology there is only one reference to theory in the index. Examining Etienne Wenger’s (1987) influential review, the entry under theories says, see Bugs, Cognitive Knowledge communication, Knowledge Viewpoints. This is in sharp contrast to the ways in which we conventionally understand theory.

One of the most powerful images we have found to describe the activity engaged in by educational technologies is that put forward by Allan Collins (then at Bolt Beranek and Newman, Inc.) who sees educational technology as a design science, similar to the O’Shea and Self vision.

Technology provides us with powerful tools to try out different designs, so that instead of theories of education, we may begin to develop a science of education.

But it cannot be an analytic science like physics or psychology; rather it must be a design science more like aeronautics or artificial intelligence. For example, in aeronautics the goal is to elucidate how different designs contribute to lift, drag manoeuvrability, etc. Similarly, a design science of education must determine how different designs of learning environments contribute to learning, cooperation, motivation, etc. Collins (1993), p. 24

These commentators on educational technology have used ideas from a range of disciplines including education, computer science, artificial intelligence, systems design, psychology, physics, engineering, human computer interaction, sociology, linguistics and many more. In this paper, we provide an examination of two of these contributing disciplines: human computer interaction and artificial intelligence in education. We make no claims about the primacy of these disciplines, but they have been extensively applied in aspects of learning technologies where computers have been used as vehicles for teaching and learning.

3 Theories in AIED

Artificial Intelligence in Education (AIED) is a discipline which has had some impact on educational technology (although it is notable that this has been limited). The aim of AIED is to apply Artificial Intelligence in educational settings. AIED is essentially an engineering discipline, which involves theoretical and practical attempts to use computer systems to mimic human teachers and/or support learners. AIED, arguably, is dominated by the use of models to provide instantiations of theories which are then used for students’ learning. Thus systems are designed to
mimic the actions of human teachers.

However, although AIED was originally focused on the development of instantiated models of teaching, students, tasks etc, there has over the last ten years been a shift towards understanding how systems work in real settings. Brna, Ohlsson and Pain (1993) discuss the role of AIED:

The continuing pressure on educators to provide high quality solutions for effective teaching and learning will be a major force for change in the next decade. The field of Artificial Intelligence in Education has an important role to play. AIED provides, and will continue to provide, theoretical analyses of the processes of teaching and learning within a wide range of context. It will further develop evaluation methodologies that more accurately reflect the educational value associated with the experience of teaching and learning. It will also increasingly deliver computer-based systems which can be used in real teaching and learning situations. Brna, Ohlsson and Pain (1993), Preface.

Baker (2000) argues that there are three uses of models of educational processes in Artificial Intelligence. These are: models as scientific tools, models as components of educational artefacts and models as the bases for design of educational artefacts. He claims that:

... a significant part of AIED research can be seen as the use of computers to model aspects of educational situations that themselves involve the use of computers as educational artefacts, some of which may incorporate computational models. Baker (2000), p. 123.

In discussing the relationship between models and theories, Baker argues that an important purpose of a model is to enable elaboration or refinement of the theory on which it is based. He is not explicit about the role of theories, but appears to see theories as being modified and refined by models.

4 Theories in HCI

Traditionally, a key framework for HCI research has been information processing and cognitive psychology, with a focus on the task and the ways in which users perform tasks. HCI is a multidisciplinary field which aims to design systems which are used effectively and efficiently. As Nardi (1996) puts it:
A key aspect of HCI studies must be to understand things: technology-physical objects that mediate activity... Nardi (1999), p. 14

However, more recently the fields has been influenced by a broader range of theories. A good example of this is the work of Hollan, Hutchins and Kirsh (2000) who argue that the theory of distributed cognition should form the basis of human-computer interaction research. They describe several theoretical principles which they claim distinguish distributed cognition from other theories of cognition. Firstly, that a cognitive unit of analysis is larger than the individual and cognitive processes occur “on the basis of functional relationships of elements that participate together in the process” wherever they may occur. Secondly, cognitive events do not necessarily occur within a human individual. Thirdly, one needs to study culture as well as cognition: “Distributed cognition returns culture, context and history to the picture of cognition.” Hollan et. al. propose a new framework for the field of HCI, using an integrated research activity map. They identify a set of core principles which are used to scope the phenomena that HCI should address. They discuss how cognitive ethnography as a method should be combined with “ethnographically natural experiments.” The relationship between the principles of distributed cognition, ethnography and experiments is crucial to the development of the field.

Rogers (2000) comments on the changes that have occurred recently in HCI:

“From what was originally a scientific enterprise with limited scope and a specific set of objectives, where cognitive theory had its place (i.e. primarily to model human computer interactions), the field has now become much more eclectic, whereby theory is increasingly being imported, adapted and applied from a diverse range of disciplines besides cognitive psychology, such as anthropology, film studies and sociology.

She discusses how HCI has moved beyond traditional cognitivism through a variety of mechanisms: abandoning theory in favour of empirical approaches, developing new terms for describing system design, importing alternative theories from different disciplines, turning to social disciplines to inform system design, evolving new fields and revising cognitive terrain. Rogers describes the range of “alternative psychological theories” including Activity Theory and Ecological Psychology. She discusses the “move to the social” – Situated Action and Ethnomethodology and the revisions made to existing frameworks including Distributed Cognition, External Cognition and the Interactivity Framework. She provides detailed descriptions, case studies and interpretations of these alternative approaches, with some assessment of their impact on HCI. Rogers argues that:
one of the main contributions of continuing to import and develop new theories in HCI is to enable new concepts and rhetorical devices to be constructed that, in turn have the potential for developing a more extensive design language, that can be used both in research and design. Rogers (2000), p. 20

It is interesting to compare this perspective on the importance of design with the views of Collins (1992) on the difficulties of carrying out design experiments in educational technology:

Typically the experiments are carried out by the people who designed some technological innovation, so that they have a vested interest in seeing that it works. They typically look only for significant effects (which can be very small effects) and test only one design, rather than trying to compare the size of effects for different designs or innovations. Further more such experiments are so variable in their design and implementation that it is difficult to draw conclusions about the design process by comparing different experiments. Finally they are carried out without any underlying theory and so these results are for the most part uninterpretable with respect to constructing a design theory of technological innovation. Collins (1992), p. 24

Collins sees the purpose of design experiments as a way to improve educational technology artefacts while Rogers is looking for the development of a design language with which to explain such experiments. It seems that there are a wide range of metaphors for design to draw on from engineering disciplines.

Mackay and Fayard (1997) make an interesting attempt to propose a framework that describes how the research and design models underlying HCI can be integrated. They make a fundamental distinction between the sciences and design and show how “HCI must necessarily draw from and benefit from both” (p. 223). They divide the contributing disciplines into natural and social sciences (psychology, sociology and anthropology) and engineering, design and fine arts (industrial design, typography and graphic design). The sciences operate within paradigms, while the engineering and design disciplines operate within schools (which dictate aesthetics and style). They discuss the different assumptions and values held by scientists and designers. They elaborate the deductive and inductive models used within science, in contrast to the design and engineering approach which involves moving from early prototypes to finished products using guidelines and rules of thumb, or principles from psychology. Their model makes an attempt to integrate scientific and design models
but perhaps their most interesting contribution is that they advocate “cross
disciplinary triangulation” which can increase the effectiveness of research.

It is unclear as yet whether these sorts of integrative approaches will bear fruit. This
discussion of HCI shows how it is evolving to include interpretations and
explanations of the culture and context which surrounds the use of systems. The goal
of HCI has not changed, in that the aim is to design usable and effective systems, but
researchers are recognising the role of context and culture and considering these in
their evaluation of systems.

5 Educational Theories

Educational theories have always influenced work in educational technology. In this
section, we will briefly describe the changes that have occurred over the past 20 years.

From the mid-sixties, the instructivist approach to designing learning situations was
popular. However, constructivism has been the dominant paradigm in learning
theories for the past 20 years. Its focus on considering how knowledge is developed
by learners through experience has been a source of inspiration for educational
technologists in the design of appropriate learning experiences. As has been reflected
in our comments about theories in HCI, one of the most significant trends of the
past 10 years has been an appreciation of the role of context and social processes in
learning. In the late 80’s a seminal paper in educational research Brown, Collins and
Duguid (1989) outlined the assumptions of the situated learning approach. Even
more recently, there has been increased attention paid to the role of social interaction
in learning, largely based upon the work of Vygotsky, with an emphasis on the role
of language and therefore dialogue. The implications of this shift have been well
explored for educational technology in Jones and Mercer (1993).

Littleton and Hakkinen (1999) in their review of current research on collaborative
learning explain the extent to which the dialogic view of knowledge construction has
had an impact on research methodologies and data interpretation in this area. They
conclude that studies influenced by Vygotskian theory have advanced our
understanding of collaborative learning, but that to make progress, we need to
integrate a fuller understanding of the cultural context of the learning situations.
6 Personal perspectives on theories used by educational technologists.

In this section we provide a brief overview of some of our own research as educational technologists. This is in order to illustrate the range of ways in which different theories and disciplines can be used for research within the field of educational technology. One of the purposes of this paper is to encourage educational technologists to go through a similar process of reflection on the sources of the theories which influence their work.

In our experience, as educational technologists, we have drawn on each of the theoretical perspectives we have so far reviewed in this paper, with the possible exception of the Ecological Psychology approach. Perhaps this is not surprising given educational technology’s interdisciplinarity. Consulting colleagues recently, we found this to be a fairly typical position for educational technologists. We see the need for some research to develop a more informed perspective on the use of theories among educational technologist, and have embarked on a project to collect views from a larger and more diverse group.

We have both found an inspiration in work on cognitive modelling from the AIED tradition. For example, this was useful in conducting an examination of difficulties in novice physics problem solving which used cognitive modelling as an analysis framework for rich accounts of students’ behaviour (Scanlon, 1990). A further example is provided in Issroff (1991) in which a system was designed to teach students about the Periodic Table, using a range of representations of the domain and providing different routes through the teaching materials which matched the students’ learning styles.

Our view of theory has also influenced our collection of empirical data. In an investigation of affective factors in computer supported collaborative learning, we conducted two types of study. The first investigated the design aspects of a simulation of the Periodic Table, using a pre- and post-test design. Our dissatisfaction with ignoring the influence of the classroom situation on the research methods led to a second empirical study which required a completely different approach, involving a naturalistic setting with an emphasis on qualitative factors and an in-depth understanding of the students and the teachers’ understanding of the learning situation (see Issroff, 1995, Issroff et al., 1997).
7 The role of theory in Educational Technology

There are no current accepted norms for the use of theories in educational technology. So, what should a theory in educational technology consist of or explain? It needs to be descriptive at minimum, that is it needs to be an account of students’ learning experience which is not contradicted by empirical observations. The theory should explain, some if not all, how a particular example of teaching material could be expected to contribute to the students’ learning experience. We are looking at how theories contribute to the design of different learning materials and how these designs in turn elicit different student behaviours – cooperation, motivation etc.

An educational technologist has to take a multi-leveled approach to understanding complex learning situations. Thus there is a need to consider the context of the institution, the culture of the students, the location of the learning situation within the curriculum as well as the design of the technology and software. In contrast, AIED with its focus on the design of systems incorporating educational and psychological theory is based on a smaller unit of analysis. The focus here is on the theories, the models and their instantiations within the systems, rather than the context in which they are used. HCI, similarly, has a focus on small units of analysis, with the main emphasis on the design of the systems and analysing the ways in which individuals interact with those systems.

These differences in the size of the units of analysis are reflected in the theories which are used by the different disciplines. It seems to us that one might even argue that there are two groups of theories in educational technologies: the first group are those which are used in HCI and AIED – ones which help us to design effective learning and teaching materials and systems. The second group are derived from education, and help us to understand the culture and context of different learning situations and their impact on students’ learning. While the former group of theories can often by modified as a result of the empirical research carried out by learning technologists, the latter group of theories are not refutable. The two different groups of theories also have different functions, in that the former enable us to have theoretically informed designs of systems and materials, while the latter impacts on our empirical methodologies and our interpretations of data. It could be argued that theories such as situated cognition, which we would describe as a group 2 theory, vastly reduce the predictive capabilities of group one theories. The culture and context of learning situations will always differ and therefore findings from a study can only conclude that certain features will have an influence on the behaviour and
learning of the students, but crucially will not be able to predict what that influence will be.

Recently, we have used Activity Theory to interpret some of this previous research and some of our more recent research (Issroff & Scanlon, 2001, Issroff & Scanlon, in press). This is an example of our use of a group 2 theory to try to understand the ways in which learning technologies impact on students’ experiences, rather than to design effective materials.

8 Conclusion

Theories are an important, but neglected area in research in educational technology. In this paper, we have tried to reflect on the theories that currently influence us in our work as educational technologists. We feel the need for theories and models which will allow us to design and refine and validate examples of learning technology and to understand the experiences of users working in the new communications and computing infrastructure of modern higher education. We are conscious that the influences on us from current broader educational theories highlight the importance of social and cultural perspectives in analysing learning situations.

In this paper we have reflected on the different types of theories which have emerged from HCI and AIED and contrasted them with the theories which are dominant in education. The continuing conversation we wish to have about the role of theories will involve collecting experiences from the educational technology community about the affordances of different theoretical influences on their work.

9 References


Systematising learning and research information
Grainne Conole

Abstract:
This paper considers the ways in which information of relevance to the learning and research communities is organised and used. It contends that there is considerable overlap between the different types of online resources and information currently available within education. It describes some of the structured environments and data stores that have emerged in recent years, along with standards which are attempting to define the properties of discrete learning objects, through the specification of Learning Object Metadata (LOM). The paper contends that current developments of structured learning environments such as Managed and Virtual Learning Environments (MLEs and VLEs) are occurring on the whole in parallel to resource data stores, such as information gateways and portals. This discrepancy has arisen in part because these developments have occurred independently of one another and in part because there has to date been no rigorous definition of the underlying theoretical models. Furthermore, it argues that these predefined structured environments are unlikely to be sufficient to meet the information needs of users in different contexts. The paper goes on to describe an information toolkit, which provides a way of systematising information handling in learning and research, which helps users articulate information plans within specific contexts. The paper concludes with a description of two case studies which illustrate how this toolkit can be used.

Keywords:
Toolkits, learning technology, information, managed and virtual learning environments, information gateways and portals, learning object metadata

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1 Introduction

The rationale for this paper comes from a recognition that the increasing sophistication of online resources and virtual environments - far from making things easier for learners and researchers - can provide a biased view or filter out information that might be of relevance to the user. Furthermore, there is a need for users to think critically about their information requirements in a specific context and then assess the relevance of different online resources to meet these needs. This paper outlines a resource, which guides and supports the user from the process of thinking about their information needs to mapping these to a specific range of resources.

Learners and researchers have a potentially vast range of resources available to them through the Internet and associated technologies. But, as the Internet increases in size and complexity, so do the associated usability and navigational issues. A range of strategies has been used to manage online information and provide different searching protocols, navigational aids and maps. Nonetheless, information overload persists. This information overload problem is well recognised and a number of structured resources and environments attempt to address it, such as information gateways and portals, digital libraries and virtual learning environments. In principle, these managed environments, with tailored views for specific individuals (or types of users), are valuable, provided that they do not limit, restrict or omit information. Even so, it is unlikely that any one of these tools will be sophisticated enough to meet the needs of every individual. In reality, users may need to adopt more of a ‘mix and match’ strategy, selecting individual features from relevant sources to meet specific needs. What users need is a specific personal set of information, hand picked from this general set and tailored to their own requirements.

At the first meeting of the Learning Technology theory group (LT-Theory 2000), there was considerable debate about the use of definitions within the area of learning technology research. In particular, the discussion focused on the fact that, by its nature, this area of research draws on a range of research disciplines: cognitive science, educational theory, computing, psychology, organisational theory, etc. Ely has recently suggested that instructional technology is not yet a discipline (Ely 1999), stating that

‘the term, discipline, is usually reserved for areas of inquiry and application that have been established over time and follow established paradigms. There is likely to be a consistency in the basic beliefs, rationales and common principles that define the scope and structure of the discipline.’
Multi-disciplinarity, in new emergent research areas, is in many respects a strength; however it also means that there is often no shared common language or set of definitions. This is evident currently in the learning technology domain, where the definition and scope of different types of online environments and resources are indistinct and, in some instances, overlapping. For example, the latest glossary of learning technology terms from the Institute of Electrical and Electronic Engineers (IEEE) states: ‘the vocabularies of learning technology, education and information technology share an ever growing number of terms yet are far from unified’ (IEEE 2002). This leads to confusion for the end users in terms of being able to clearly articulate their information needs and uses. In particular users are generally unclear about how to translate their information needs into the correct terminology in order to be able to locate the information they need. This problem is caused, in part, by the lack of consistency in the vocabularies used by different information providers. This paper provides a practical approach to addressing such needs, through the use of a structured decision-making resource for information handling, which enables users to develop tailored information plans for specific contexts. This paper will describe the philosophy behind the development of this information toolkit and report on the evaluation of its use to map the information needs of two different users.

The paper is divided into two distinct parts. The first half of the paper looks at the different ways in which information is organised and discusses some of the current issues of information overload and multiple information sources and in particular it outlines the problem of the complexity of locating information. The second half suggests some guidance on one approach to helping users address this complexity and describes a toolkit to help academic uses of information to access and manage their information needs.

2 The information landscape

We are all too aware of the impact of increasing information overload and in principle would agree that providing tailored views for specific individuals or types of users is valuable, provided that this is not at the expense of limiting or restricting information and omitting items which may be of importance. This information overload problem is well recognised and a number of tools and resources exist; such as search engines, information gateways and portals, digital libraries and online datasets and virtual learning environments. This paper contends that there is considerable overlap between these different systems and that what users really need is a specific personal set of information, hand picked from this general set and tailored
to their own needs and requirements. The rationale for this paper comes from recognition that the increasing sophistication of online resources and virtual environments - far from making things easier for learners and researchers - can provide a distorted or biased view or filter out information that might be of relevance to the user. Furthermore it is clear that there is a need to enable users of online tools to think critically about their requirements and use of these resources in this context. This paper attempts to provide this type of guidance by presenting a framework that guides the user from the process of thinking about their information needs to mapping these to a specific range of online resources. It begins by contextualising this work and illustrating examples of online resources for learning and research.

### 2.1 Categorising online resources and information

In recent years developments in Information and Communication Technologies have led to a growth in the range of Internet-tools which can be used for learning and research. Some have now gained wide scale acceptance (for example, email); others seem to find either niche applications or are less pervasive than one might have first imagined (for example, video conferencing).

Research and development into the creation of digital libraries and online portals has developed to a large extent in isolation from research and development into the creation of online learning resources and virtual learning environments. Developments are now emerging into the creation of institution-specific online environments or resources and the development of tailored Managed or Virtual Learning Environments (MLEs and VLEs), information portals and gateways, and personalised desktops. An obvious question in relationship to these developments is, what defines and distinguishes a MLE from a VLE from an information portal or gateway? What are the components that make up a M/VLE or gateway? How much do we know or understand about how they are used or how well they meet user needs?

This lack of clarity and clear definitions of what differentiates VLEs, MLES, gateways and portals is a in part characteristic of learning technology as a new and emerging area of research, but is also systematic of a lack of understanding within the community and in particular the lack of a shared language with which to develop and consolidate ideas and definitions. The toolkit described in the second half of this paper is an attempt to address this by providing a mechanism for creating a shared meta-language and a means of structuring and categorising different information processes. The value of meta-language through the use of toolkits was also evident in
the use of Media Advisor with a group of teachers from different subject areas. The study found that the toolkit allowed the practitioners to share and interpret each other’s understanding of learning and teaching within their subject domains (Oliver, MacBean et al. 2002).

This paper contends that we need to gain a better understanding of the information tools and methods that make up MLEs, VLEs, gateways and portals, in order to be able to fully utilise their potential and in particular how they can be used in different contexts by different users. The paper suggests adopting more of a ‘pick and mix’ strategy for creating personalised environments, rather than trying to produce an ‘all-embracing’ solution to meet the needs of everyone. The paper describes an Information Toolkit to facilitate this, which helps the user map information tools and methods to information activities. Use of this toolkit, supports users in critically evaluating resources according to particular needs. It can help the user to gain a better understanding of the potential of current technologies to support particular learning and research activities. The explicit mapping of information tools and methods to particular activities should also inform the debate on the development of future structured learning environments for particular groups of users or specific needs. This section describes the different types of structured learning environments and their constituent components. It outlines the way in which these are now being specified at both the macro-level, via a Learning Technology Systems Architecture (LTSA) and at the micro-level, through the definition of Learning Object Metadata (LOM).

2.2 Managed and virtual learning environments

In the last five years, Virtual Learning Environments (VLEs), which integrate communication tools (email, discussion boards, etc), with learning resources and assessment tools, have emerged in order to support learning. This has lead to the development of a range of home-grown institutional solutions, whilst offerings of ‘Commercial Off The Shelf’ (COTS) solutions (WebCT, Blackboard, Lotus Learning Space) abound. Although initially targeted to support learners, many of these are also being used as intranets or for information storage. Many of these purport to the notion of providing a ‘holistic’ learning environment and intimate that these types of environments are well suited to supporting student-centred learning and constructivist ideals. Whilst, Laurillard’s conversational model (Laurillard 2001) and her mapping of methods with educational activities, are not out of step with these notions, this should by no means be taken as read. These environments are equally able to support bad practice as well as good. Laurillard et al. have espoused the
importance and role of narrative structure in supporting learning and, in particular, an investigation of the design features that ‘afford’ activities that generate learning (Laurillard, Stratfold et al. 2000). Put simply, it is not the environments themselves that support or enhance learning, but the ways in which they are used. Narratives to aid understanding, navigational guides and scaffolding strategies are all crucial, but can only be put in place once there is a clear understanding of the underlying components and how they can be used. This work suggests there is a need for a much clearer understanding of VLEs and the ways in which they are be used to support learning and that coherence will not arise until these components are understood. Many universities are now looking beyond the development of VLEs to more encompassing Managed Learning Environments (MLEs) and this introduces an additional level of complexity. The components of a Managed Learning Environment (MLE), which integrate or ‘join-up’ the VLE with the university’s management systems, might include a wide range of functional components - administrative information about courses, resources, support and guidance, collaborative information, assessment and feedback, and evaluation (taken from a report by JISC (ASSIST 2000). Whilst, as described above, VLEs at least purport to support a constructivist approach to learning, it is unclear what theoretical basis MLEs align to. Therefore, here, too, there is a need to understand the relationship between these components and the strategies which can be included to better support their use.

2.3 Information gateways and portals

A number of niche information gateways have developed. In the UK the main gateway for Higher Education is the Resource Discovery Network (www.rdn.ac.uk), similar gateways exist in Europe and elsewhere (Renardus 2001). The term ‘gateway’ is used to describe a range of Internet sites that in some way provide access to other, predominantly Internet-accessible, resources. Gateways are intended to facilitate resource discovery by their target audience, to help their users find what they need via the Internet. ‘Information Gateway’ is a generic term that refers to a whole range of Web-based resource guides pointing to Internet information resources, whereas ‘Subject Gateways’ are subject-based resource discovery guides that provide links to information resources (documents, collections, sites or services), predominantly accessible via the Internet (definitions taken from (Renardus 2001). Resource description and subject classifications are the most important characteristics of such guides. In addition, it is becoming more common for publishers to make journals and books available online, as well as online data archives, collections, etc. Considerable thought is being given to how users can access and use these resources in a coherent way; a good example of this is a recent definition of a portal architecture by Powell. In his paper, he defines a subject portal as something that
‘...brokers’ end-user access to a range of services, relevant to a particular subject area, over a number of application protocols (LDAP, Whois++, Z39.50, ILL, FTP) [and]...provides ‘discover’, ‘locate’, ‘request’ and embedded ‘use’ ...functionality’ (Powell 2000). Powell goes on to describe the architecture for a portal. He defines six types of ‘player’: the end-user, presenters, coordinators, mediators, communicators and providers, and describes the roles and relationship between them. At the ‘bottom’ of the architecture are the information providers, such as subject gateways, data archives, service providers and collections. Clearly, these systems represent a rich variety of structures, supporting a range of applications. As with VLEs and MLES outlined above, there is a need to better understand the fundamental components of these systems and their affordances.

It is also evident that the boundaries between VLEs for learning and portals for research are blurring and that many of these systems are starting to provide additional functionality beyond their original scope. For example, the Social Science research gateway, SOSIG, primarily focuses on the development of a quality-assured set of resources of relevance to the social science research community. However it also includes a facility to develop personal profiles, ‘My SOSIG’, and the ability to network with ‘likeminds’ using its grapevine facility. SOSIG is also linked closely to a set of online tutorials which provide an introduction to the Internet (Virtual Training Suite, available online at http://www.vts.rdn.ac.uk.). Similarly VLEs are often now used as gateways or portals to specific types of resources of relevance to a particular learning programme. These developments suggest that an evolution is in process, namely that an information source, once established, starts to adapt according to user needs.

The description above illustrates the rich variety of structured information environments that have developed over the past five years or so. It is evident that despite addressing different initial needs (for example resources for the research community or support for a distance learning programme), these systems are now converging in terms of functionality. In an attempt to better understand and define the different forms of structured learning environments, an overarching framework (the Learning Technology Systems Architecture, LTSA) has been developed as part of the IEEE standards work (IEEE 2002). The LTSA specification covers a wide range of systems (learning technology, computer-based training, electronic performance support systems, computer-assisted instruction, intelligent tutoring, education and training technology, metadata, etc.) and is intended to be pedagogically neutral, content-neutral, culturally neutral, and platform-neutral. It aims to provide a framework for understanding existing and future systems and promoting interoper-
ability and portability by identifying critical system interfaces. The purpose of developing system architectures is to

'discover high-level frameworks for understanding certain kinds of systems, their subsystems, and their interactions with related systems... An architectures isn’t a blueprint for designing a single systems, but a framework for designing a range of systems over time and for the analysis and comparison of these systems... By revealing the shared components of different systems at the right level of generality, an architecture promotes the design and implementation of components and sub systems that are reusable, cost-effective and adaptable' (IEEE 2002)

In theory, therefore, it should be possible to map all MLEs, VLEs, portals and gateways to this overarching LTSA and in so doing see the relationship between these different systems. By more clearly articulating this underlying architecture and identifying the relationship between the different expressions of this architecture, we should be able to gain a better understanding of these systems and more importantly what features ‘afford’ activities that support learning or facilitate the gathering or using of information and resources.

2.4 Learning objects

At the other extreme to the concept of all-encompassing online environments is the idea is that one can define ‘objects’ as the basis for combining and re-purposing resources and data according to needs and interest, or for categorisation of information. The IEEE have developed a set of guidelines for definition Learning Object Metadata (LOMs) and an associated specification (LTSC 2001). This standard:

'specifies the syntax and semantics of learning object metadata, defined as the attributes required to fully and adequately describe a learning object. A learning object is defined here as any entity, digital or non-digital, that can be used, re-used or referenced during technology-supported learning. Examples of technology-supported learning applications include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, web-based learning systems and collaborative learning environments'. (LTSC 2001)
However, as Wiley points out the IEEE definition is very broad (Wiley 2002). Various attempts have been made to narrow the scope of the definition down to something more specific. The proliferation of definitions for the term “learning object” makes communication confusing and difficult. Wiley concludes that:

"An in depth discussion of the precise meanings of each of these terms would not add to the main point of this discussion: the field is still struggling to come to grips with the question, What is a learning object?"

Similarly one of the reviewers of this paper comments:

“I always feel a bit uneasy if there is not a conceptual distinction between the terms objects and resources. To me, “objects” implies more than just resources. For instance, consider a multiple choice item. The item itself (the wordings in the stems, the options and answer) is “resources”. When the system can present this with interactivity (i.e. a learner can indicate a choice and submit the choice to some VLE), it is a learning object. Some may like to call the software component which provides the interactivity "object" and still makes a distinction between the "interactive" part and the "resource" part. …. LOM can and should be used to describe ANY resource and hence enabling resources to be used effectively.”

The LOM standard focuses on the minimal set of properties needed to allow learning objects to be managed, located, and evaluated. Relevant properties of learning objects include type of object, author, owner, terms of distribution, and format. Where applicable, learning object metadata may include pedagogical properties, such as teaching or interaction style, grade level, mastery level and prerequisites. This approach in essence assumes a positivist, rational view of information and knowledge. Underlying this approach is the vision that by having clear and specific definitions, it will be possible to search, acquire, evaluate, use, share, and combine different learning objects. At a practical level, this suggests that a student could build up their own tailored set of learning resources gathered from a range of sources and adapted to their particular learning needs. Educational establishments would be able to re-purpose their materials and exchange resources with other institutions. In essence these conventions could give us a ‘grammar’ for information, with MLE, VLEs, portals and gateways becoming expressions using this.

Nonetheless, there are still a number of unresolved issues with this positivist, rational approach. Firstly, there is concern over the conflict between the degrees of
granularity that will be necessary for different learning objects to provide a sufficiently detailed description, whilst also providing sufficient flexibility of use. The scope of what defines a learning object is not clear, ranging from little more than raw digital assets through to large 'chunks' of learning materials or courses. Secondly, this static set of rules does little to tell us about what these LOMs mean in terms of what they can 'afford' for learning or research (Gibson 1979). If we can gain a better understanding of these objects and the ways in which they can be combined, we can go some way towards grouping and tailoring information to specific user needs. Then it would not matter if at the macro-level we talked about a VLE or a portal: the underlying architecture would be the same.

2.5 Summary

Thus information can be categorised on the one hand into some form of higher-level structure, designed to meet the needs of a specific type of user, or alternatively can be categorised in terms of learning objects, with tightly defined associated properties. However, the increasingly rich array of sources and types of information now available means that it is unlikely that any one VLE, MLE, gateway or portal is going to provide all the information needs for a particular user within a specific context. It is also unlikely that just defining resources in terms of a set of component learning objects, is going to provide enough support to enable users to derive maximum benefit from these resources or to support them in using these resources to meet particular needs. Furthermore, simply grouping these learning objects into different contexts to build tailored VLEs, MLEs, portals or gateways, won't work adequately either. In reality, users need to construct their own information needs using a variety of strategies, which include aspects of the above as appropriate. The information toolkit outlined in the remainder of this paper is designed to help users to articulate their information needs and construct personalised information strategies for a particular need. It is a technique to enable users to engage critically and questioningly with the messy world of information in a way that reflects their own values, needs and beliefs.

Furthermore, Bruce argues that there's more than one way to think about what counts as "effective use" of information, and that if we concentrate on technological issues (of access, architecture and functionality) we miss arguably the more important issues of building new knowledge or wise, authentic and personalised use of information (Bruce 1997). The information toolkit outlined in the next section attempts in part to address this.
3 The information toolkit

The previous section illustrates the complexity and range of online environments and highlights the need for guidance and support mechanisms to help users navigate, find and utilise online resources. This section describes one approach to providing this form of expert guidance, through the use of a decision-making resource, an information toolkit, which can be used to facilitate information handling and processing.

A range of resources to facilitate decision-making processes has been developed to support the use and integration of learning technologies. In essence, decision-making resources range from highly restrictive ‘templates’ or ‘wizards’, which provide high levels of support and step-by-step guidance but little possibility of user-adaptation, through to ‘theoretical frameworks’, which provide a context and scope for the work but leave the user to devise their own strategy for implementation. Between these extremes lie a range of resources, including checklists, guidelines and step-by-step tutorials. This paper describes a toolkit for systematising information needs. A detailed definition of our use of the term toolkit is defined and illustrated elsewhere (Conole 2000; Conole and Oliver 2001).

The information toolkit adopts a similar approach to two related toolkits, ‘Media Advisor’ (Conole and Oliver 1998; Oliver and Conole 2000) and ‘Evaluation Toolkit’ (Conole, Crewe et al. 2001; Oliver, MacBean et al. 2002). It provides a means of mapping information resources against types of information activity (grouped in the toolkit into four categories: gathering, using, communicating and evaluating). This gives the user a clearer view of the resources they are using, why they are using them, and allows them to form their own tailored information plan. The toolkit guides the user through the process of articulating their information needs and results in the production of an information plan for a particular task. The ‘scope’ of the task is one of the first stages of working through the toolkit; a task could range from considering all the information needs for a course module, a research programme or a development project.

The information toolkit consists of the following key steps:

1. Scope. Articulation of the scope of the information plan – who is this for, at what level, how long will it be used for?
2. Purpose. In this step the user considers the four information activities and specifies the relevance (or not) of each to this particular plan and the specific purpose of each activity.
3. Mapping. This final stage involves mapping the tools and methods to the information activities to produce the Information plan.

3.1 Scoping the plan

In this section of the toolkit the user articulates the scope of the information plan. This scoping is important because it will help the user to filter out inappropriate information sources, which may be too difficult, too rudimentary, or of secondary importance. The user may choose to describe the scope in some detail or with a rough sketch, whichever is appropriate. The scope helps them to focus on what they are gathering and using the information for; are they seeking information for a review, writing a report or essay? or conducting a piece of research work?

Table 1: The Scoping Table: Defining the scope of the information plan

| Questions               | Illustrative examples                                                                                                                                                                                                                                                                                                                                 |
|-------------------------|                                                                                                                                                                                                                                                                                                                                                     |
| Description             | At a minimum the scoping stage should provide a description of the area of interest. Is this plan to be produced to support a student on a particular module? Is it information being gathered to support a research project, or relevant material for a journal review? Is it concerned with all the information needs associated with a consortium-based development project, with a view to forming a shared project resource? |
| Primary Stakeholder     | This is most likely to be the person designing the information plan. Details here could include something about the person; are they a researcher, an undergraduate, a project manager? These details could be important in terms of given an indication of the quality and the level of the information plan, if it were reviewed by anyone else, for example as a case study for other users. |
| Secondary Stakeholder(s)| These are others who might be interested in the plan. Examples might include fellow students on a course. For example, students might divide the information ‘mining’ for a set of modules on a course and agree to use them together as a shared resource. Another example of a secondary stakeholder could be the tutor for a course or a reviewer for a research project. |
3.2 Defining information activities

This section considers the different types of information activity that are important in the plan. The classification used here is similar to the approach used in the Media Advisor toolkit (Conole and Oliver, 1998; Oliver and Conole, 2000), where four groupings were used to classify educational activities (delivery, discussion, feedback and activity). Of course this approach is a simplification: information activities can be classified in a number of different ways and to a greater degree of granularity (indeed Laurillard’s conversational framework identifies twelve tutor-student interactions (Laurillard, 1993)). However, as with Media Advisor, the purpose here is not to provide a rigid classification, but to give enough guidance for the user to make informed decisions. A reasonable starting point therefore is that manipulation of information can be grouped into the following four categories:

- Seeking or gathering
- Processing or using
- Communicating or disseminating
- Evaluating or monitoring

The Learning Technology Systems Architecture specification described earlier defines information in terms of data processes, stores and flows (see Figure 4, page 23 of http://ltsc.ieee.org/doc/wg1/ltsa/ltsa_05.pdf). The four information categories outlined above map to this as outlined in the figure below. Data stores act as both

<table>
<thead>
<tr>
<th>Level</th>
<th>What level of difficulty is the information to be pitched at, for example degree or graduate level? What type of audience is it aimed at, for example learners, researchers or a commercial audience?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timescale</td>
<td>Is this for a particular task over the next six months or is it a general information plan for an ongoing research interest?</td>
</tr>
<tr>
<td>Resources</td>
<td>Who will be gathering and using the information apart from the end-user? Is there a research assistant involved in data collection, for example?</td>
</tr>
<tr>
<td>Other</td>
<td>In this section the user is encouraged to articulate any other relevant information to include in the scope of the plan, which will help them to focus on particular uses and sources of information in the next section.</td>
</tr>
</tbody>
</table>

Journal of Interactive Media in Education, 2002 (7)
vehicles for storing or receiving information. A user can seek, gather, evaluate or monitor information from a data store, or alternatively can communicate or disseminate information back (for example by depositing information in a data store). Therefore data stores are linked to different data processing activities, via gathering, communicating or evaluating.

Table 2 illustrates the four information categories defined above in terms of their typical roles in both learning and research. (For simplicity these classifications will be referred to in future as 'seeking, using, communicating and evaluating'.) The user will then use this table to begin to identify which of the four information activities are relevant to their own information plan. In some cases all four of the activities will be involved - for example in the production of an undergraduate research project, where the user needs to gather background information on the research topic, process relevant information and communicate the results in the form of a dissertation paper. The evaluation in this case will be by the tutor in terms of marking the report. In
other cases, a plan might focus on only one or two activities, such as carrying out a literature review at the start of a research project.

**Table 2: The Classification Table: Classification of information activities**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Purpose</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathering or seeking</td>
<td>To gather information to support learning or specific activities. Information about a course, the university, other resources, relevant related materials, examples of introductory guides.</td>
<td>To gather information for a literature review, to support a research paper, or to keep abreast of current developments. Information about research centres or individuals of relevance to a particular research activity.</td>
</tr>
<tr>
<td>Using or processing</td>
<td>Manipulation of data or resources to carry out a specific learning task.</td>
<td>Analysis of data collected using standard qualitative and quantitative research tools and methods.</td>
</tr>
<tr>
<td>Communicating or disseminating</td>
<td>Student-tutor: for checking, for support, administration or feedback.</td>
<td>Communication with research peers to share or explore ideas, or with project partners, or to the wider research community to disseminate findings.</td>
</tr>
<tr>
<td>Evaluating or monitoring</td>
<td>Assessment of students, monitoring and feedback on progress.</td>
<td>Research assessment exercise, peer review through journals and conferences, success in securing funding.</td>
</tr>
</tbody>
</table>

**3.3 Mapping the tools and methods to information activities**

This part of the toolkit gets the user to brainstorm what information will be gathered and for what purpose. The user is presented with a range of information sources and resources (mailing lists, email, journals, books, seminars, etc) and asked to focus on the four types of information activities (seeking, using, communicating and evaluating). They are asked to consider:
• What types (or specific) information they need to gather
• What they will do with it
• How they will communicate it and to whom
• How they intend to monitor/evaluate or be monitored/evaluated

In Media Advisor, users then map the learning and teaching methods (including both ICT and traditional approaches) against educational activities, to give a picture of their own learning and teaching approach. Similarly, Table 3 outlines how different types of ‘information’ can be classified under four main headings (seeking, using, communicating or evaluating). By providing a map of the relationship between information activities and sources, the user can apply this knowledge to articulate their own individual map for specific types of activity. The map is not restrictive: the user can define additional tools or methods and can choose to adapt the information activities if they wish. The idea is to give them some structure to their thinking. It aims to guide the user through these stages and helps them to articulate different resources.
Table 3: The Mapping Table: Mapping of tools and methods with information activities

<table>
<thead>
<tr>
<th>Tools and Methods</th>
<th>Information activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seeking</td>
</tr>
<tr>
<td>Subject-gateways/digital libraries</td>
<td></td>
</tr>
<tr>
<td>Online resources (course materials, tutorials, CAL packages)</td>
<td></td>
</tr>
<tr>
<td>Mailing lists, Newsgroups, Discussion boards</td>
<td></td>
</tr>
<tr>
<td>Conferences, seminars, Presentations/workshops/lectures</td>
<td></td>
</tr>
<tr>
<td>Online Journals, books, etc</td>
<td></td>
</tr>
<tr>
<td>Paper-based books, leaflets, etc</td>
<td></td>
</tr>
<tr>
<td>Search engines</td>
<td></td>
</tr>
<tr>
<td>Email</td>
<td></td>
</tr>
<tr>
<td>Intranet</td>
<td></td>
</tr>
<tr>
<td>Peers</td>
<td></td>
</tr>
<tr>
<td>Tracking or assessment software</td>
<td></td>
</tr>
<tr>
<td>Data gathering using research instruments (questionnaires, observation, video logs, focus groups, etc)</td>
<td></td>
</tr>
<tr>
<td>Databases or data archives</td>
<td></td>
</tr>
<tr>
<td>User defined tools and methods</td>
<td></td>
</tr>
</tbody>
</table>

The user includes in each cell details of the way in which each of the tools and methods are used with respect to each of the information activities. Only those cells, which are relevant to the user’s information needs, are completed. This map gives a quick visual representation of the information plan and can be updated as necessary.

On a first iteration through this table the user is likely to identify generic sources of information, highlighting the types of tools and methods which are likely to be of
most use and eliminating irrelevant ones. On subsequent iterations the user can start to build a picture of specific examples (eg ‘this journal’, such and such a person), until they are satisfied that they have a comprehensive plan.

3.4 Case studies

This section describes the results of using the toolkit in two case studies. The methodology used was to guide each user through the toolkit, prompting additional explanations where necessary and following up with a semi-structured interview (to access the users’ impressions of the toolkit and to gain insight into its value). The case studies are intended only to be illustrative of the ways in which the toolkit might be used. It would be interesting to extend these studies to different types of users and different information searching tasks. In particular a case study on a first-year undergraduate student starting a piece of learning that could be more ‘surface’ than ‘deep’ would be a good example of the use of the toolkit.

3.4.1 Case study 1: online resources for a learner

The learner described here is a student studying for a MSc in Information and Library management. The toolkit provides a mechanism for the student to articulate the different types of information resources being used to support the course and the ways in which each of these is being used. It can be used as a starting point to gather information, but the more significant benefit is that it can be used as an ongoing tool for learning, which can reflect the students’ changing work pattern. By sub-dividing information use and processing, the toolkit helps the student to think clearly about each type of information and its relevance to them, whilst also allowing them to articulate the ways in which their work will then be represented.

The student was first briefed that the aim of working through the toolkit is to provide structured guidance on the gathering and use of information, and that by the end the student should have developed a comprehensive information strategy to support a particular learning activity or course. The four fundamental aspects of the types of information activity that the toolkit supports are then introduced and explained, using the Scoping Table (Table 1) as an illustration. The different types of information sources, resources and channels are then presented as outlined in the Classification Table (Table 2). The student then brainstorms the types of ways in which (s)he gathers and uses information and, using the Mapping Table (Table 3), begins to complete an information plan. An example of the partially completed information plan for this student is illustrated in Table 4. In this example the table

Journal of Interactive Media in Education, 2002 (7)
does not include specific details of links for reasons of anonymity, but in reality this would be an important part of the plan. The information plan forms a summary of links to relevant resources, details of conference and event dates, and deadlines for papers or abstracts. In essence therefore the plan is a form of extended ‘bookmarking’ system which brings together online and other sources of information.

The process took about 30 minutes to complete; the student had little trouble working through the toolkit or completing the tables and appeared to need minimum clarification. She was clear about the function and value of the toolkit and could see its relevance to her own working practice.

“This is a helpful tool, because you are working on your own as a part-time student and don’t necessarily have the same support as a full-time or undergraduate student might.”

In particular, she commented that having completed case studies of the toolkit to refer to would be valuable, although she did express some reservation that these might hinder creativity and impose some restrictions on the way a user would then complete their own plan.

“Having the case study approach gives you ideas of where to look, but you would need to be careful as this could also limit or restrict your scope. Anything that makes things easier is good!”

In her opinion, the toolkit would require a small investment of time initially, but this would be beneficial in the long term as it would provide a structured record of relevant resources which can easily be updated or adapted.

“It would take longer to work through this tool initially and quicker after, however this is time well spent as this is the most important part of a research project like this.”

Finally, although she could see the benefit of the toolkit and the final information plan, she was unconvinced that it would fundamentally alter her strategies for searching and using information.

“Useful to have the information all together in this format. I don’t think this tool would have made me do the research any differently though.”
3.4.2 Case study 2: mapping information resources for a researcher

This case study was carried out with a PhD researcher in philosophy. As with the first case study, the researcher was provided with an initial overview of the purpose of the toolkit, its components and the expected outcomes of the process. Guidance was provided through each stage of completing the information plan, prompted with further explanations or examples where necessary.

Table 5 shows the researcher's partially completed information plan. The researcher began by defining the scope of his information plan, using Table 1 as a guide. After brainstorming the ways in which he used different types of information, using Table 2, he mapped his tools and methods with the information activities to produce an information plan, as illustrated in Table 5. Running through the toolkit with this researcher took about thirty minutes, and was followed by a short semi-structured interview to gain first impressions on its potential value. The researcher found the toolkit easy to use and was clear about its purpose; for example, when he was introduced to the second part on identification of information activities, he said:

“As a researcher I can relate very easily to the examples of different types of information activities given as examples for research.”

In some places he was unsure which cell to put an entry in:

“A difficulty with this is that each resource plays so many roles, it can be difficult to attach a resource to an individual cell.”

However, he did not feel it obstructed his information plan. One strategy he used to get round this was to combine cells across one or more information activity. This user adaptation is an important underlying assumption of these types of decision-making resources. This process of guiding the user through a set of choices, whilst maintaining user freedom by allowing them to customise or add to entries is an integral feature. He clearly found the information toolkit valuable and observed the following:

“Part of the role of a researcher is as a ‘librarian’ to the subject area, to introduce other researchers to the area. This toolkit helps to divide up and recommend relevant resources according to the four categories. It makes me think of how to prioritise and the overview helps me to articulate how to prioritise the balanced use of these different resources. I could imagine giving conditional recommendations, i.e. using my knowledge to fill in the gaps of other researcher’s information plans. I could also imagine using this system as a basis for organising my online bookmarks and address books into these categories.”

Journal of Interactive Media in Education, 2002 (7)
4 Conclusion

This paper has argued that we do not yet have a clear enough understanding of the way in which information can be best structured to support particular learning or research activities. It has reviewed the different ways in which information can be structured or defined both at a macro-level (in the form of the Learning Technology Systems Architecture) and a micro-level (by tightly defined learning objects and associated metadata). However, it contends that there is still a need for users to critically assess their own information needs in context. The paper has described an information toolkit which can be used to guide learners and researchers through a structured process of thinking about the ways in which they gather and use information to support particular activities. The toolkit has been piloted with users from both domains and initial evaluation feedback has been positive. By specifying the terms of reference for the area in the form of a toolkit the user is guided through the thought processes and sequence stages which are relevant to the problem. An additional benefit is that the toolkit can be used to generate a suite of these types of information plans. These plans can be used as templates for new users, which they can then adapt and update for their own needs.

Evaluation with users so far suggests that there are three potential levels of use for this toolkit. Firstly, it can be used by an individual to articulate an information plan for a particular task, however large or small. An initial plan can be developed quickly and then iteratively build up over time. Secondly, information plans can be shared with peers or aggregated to form a series of templates for particular information areas, in the same way that the Evaluation Toolkit can be used to generate evaluation case studies for common types of evaluation. Thirdly, construction of these types of information plans gives an insight into the information requirements of different types of learners and researchers, and a critical analysis and evaluation of these patterns would give a fascinating insight into the cultures of different information users and the development of new user interfaces to existing information resources. It is also important not to neglect associated issue of quality in relation to the use of the toolkit. For example at what point does the user judge the quality of the resources identified and do they have the necessary skills to be able to make those judgements?

One of the benefits of toolkits is that they make it possible to move away from an “expert knows best” mindset to one in which each user is viewed as an expert in their context, which helps to empower the user to develop the necessary skills to make their only locally-situated judgements. Furthermore it is important to stress that toolkits are not solutions, they are designed to be educative in nature. The user has to build their own representation of knowledge sources and therefore they need to think about what’s available, why it might be good, and how it all relates - tasks that are automated in an expert system (cf. wizards). So toolkits require more effort by the user, but there are longer-term educative pay offs. One potential shortcoming of this
approach is that it assumes that the user is aware of all possible sources of information that may be relevant to them. One solution would be to develop a more interactive form of the toolkit which would include reference materials and guidance on different sources of information which the user could dip into as needed. This is similar to the approach adopted in the Evaluation Toolkit, where the user is guided through the processes of data collection and analysis through a series of filtered resources and further information (Conole, Crewe et al. 2001). The issue of whether or not a ‘pick and mix’ strategy for gathering and using information as proposed in this paper is better than the alternative one stop shop of a unifying point for information as purported in many portal developments and in the recommendations from the SoURCE evaluation (Beetham, Taylor et al. 2001) is not yet clear and will need to be investigated further.

Clearly one of the strengths of the one-stop approach is that it provides a simple and structured interface for the users. A disadvantage is that the scope has to by definition be predefined. An advantage of the toolkit approach is that it allows the user to tailor their information plans and as the model is flexible the user can adapt and update as appropriate. A disadvantage is that this presupposes that the user has the necessarily information seeking and handling skills to best utilise this and that they are aware of different information sources. It is worth ending this paper by noting the perspective of one of the reviewer of this paper who states that:

“In the user needs analysis for the Main SoURCE Evaluation Report on the Re-usable Educational Software Library (reported in Beetham, Taylor & Twining 2001) a clear demand was expressed for one integrated access point for resources (relating to learning technology practice). This seems to be in conflict with the approach being advocated in this paper. Clearly, in the short term, a pick and mix approach is the only viable one. However, I would argue that we need to be looking to move towards much greater integration of information sources in the future (though I acknowledge the complexity of this - particularly in the light of the context specific nature of metadata).”

Whether or not this is true remains to be seen, but it is clearly evident that a substantial amount of research and developed is still needed before the dream of a comprehensive rich use of the wealth of information now available on the Web and elsewhere is realised and but to best effect.

Acknowledgements

I would just like to note my thanks to the referees for their very detailed and helpful comments on this paper. The paper has been updated significantly as a result of their comments and is much better as a consequence. My thanks also to Martin Oliver for providing lots of valuable feedback and for, as always, making me think about what I haven’t written (too!) hard.
Table 4: Case study 1: partially completed information plan for a masters student

| Information Plan: To support a masters dissertation on user education on the Web. |
| This plan will focus on the information plan for the final dissertation module. This was a critical module in the masters, as failure to pass this would have meant failure in the overall masters |

<table>
<thead>
<tr>
<th>Scoping details</th>
<th>Information activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Gathering</td>
</tr>
<tr>
<td></td>
<td>Using</td>
</tr>
<tr>
<td></td>
<td>Communicating</td>
</tr>
<tr>
<td></td>
<td>Evaluating</td>
</tr>
<tr>
<td>Purpose</td>
<td>The purpose of gathering information was to find out what was going on in the field to test the hypothesis of the research project and to compare findings, and the learners perspective with the wider body of information in the field.</td>
</tr>
<tr>
<td>Purpose</td>
<td>The learner did all her own primary research (which consisted of the development and use of a questionnaire and semi-structured interviews). In addition, she used the findings from the research literature and from colleagues to compare her results.</td>
</tr>
<tr>
<td>Purpose</td>
<td>Production of a final report for the dissertation, summarising the results and findings.</td>
</tr>
<tr>
<td>Purpose</td>
<td>Assessed by course tutors and external examiner for the programme as part of the masters.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools and Methods</th>
<th>Information activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathering</td>
<td>Using</td>
</tr>
<tr>
<td>Subject-gateways/digital libraries</td>
<td>Communicating</td>
</tr>
<tr>
<td>Online resources (course materials, tutorials, CAL-packages)</td>
<td>CITI Library and management information resources</td>
</tr>
<tr>
<td>Mailing lists, Discussion boards, Newsgroups</td>
<td>Us-eib</td>
</tr>
<tr>
<td>Conferences, seminars, Presentations, workshops, lectures</td>
<td>IF/IA and the online papers from the conferences</td>
</tr>
<tr>
<td>Online Journals, books, working papers, etc</td>
<td>Managing information</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td>Aslib proceedings</td>
</tr>
<tr>
<td></td>
<td>Journal of academic liaisonship</td>
</tr>
<tr>
<td></td>
<td>Academic libraries as high tech gateways</td>
</tr>
<tr>
<td></td>
<td>Journal of Information Science</td>
</tr>
<tr>
<td>Paper-based books, journals, leaflets, etc</td>
<td>Colleagues dissertation report on a related topic</td>
</tr>
<tr>
<td></td>
<td>Program</td>
</tr>
<tr>
<td></td>
<td>Library associate record</td>
</tr>
<tr>
<td>Search engines</td>
<td>Google, yahoo</td>
</tr>
<tr>
<td>Email</td>
<td>Distributed research instruments via email to the targeted group of subjects</td>
</tr>
<tr>
<td>Intranet</td>
<td>The course Intranet— including submission details and dissertation guidelines</td>
</tr>
<tr>
<td>Peers</td>
<td>A colleague’s (who had completed a similar masters the year before) bibliography on a related topic</td>
</tr>
<tr>
<td></td>
<td>Validation of initial analysis with peers</td>
</tr>
<tr>
<td></td>
<td>Update on progress with course advisor</td>
</tr>
<tr>
<td>Tracking or assessment software</td>
<td>Developed own research instruments— questionnaire and semi-structure interview</td>
</tr>
<tr>
<td>Data gathering using research instruments</td>
<td>Bids</td>
</tr>
<tr>
<td>observation, video logs, focus groups, etc</td>
<td>IBI</td>
</tr>
<tr>
<td>Databases or data archives</td>
<td>Excel to analysis data and identify emergent themes</td>
</tr>
<tr>
<td>User defined tools and methods</td>
<td>Production of dissertation report</td>
</tr>
<tr>
<td></td>
<td>Submission of report for assessment</td>
</tr>
</tbody>
</table>

Note: the acronyms used in this table are not expanded as it is not the resources themselves that are of interest in this paper, but the concept of the ways in which information resources can be mapped to the information toolkit categories.
Table 5: Partially completed information plan for a postgraduate research student

<table>
<thead>
<tr>
<th>Information Plan: To support a thesis on ‘Epistemic values’ and related research papers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td>Gathering: Primarily a literature search, identifying related researchers in other institutions, also online papers and relevant journals. Looking for illustrative examples from other disciplines.</td>
</tr>
<tr>
<td>Communicating: Application of a range of qualitative research techniques, summarising and comparing information, evaluating arguments and critiques.</td>
</tr>
<tr>
<td>Evaluating: Submitting ideas or works in progress to other active researchers in the field; acquiring further literature recommendations, submitting to relevant formal and informal publications and dialogue.</td>
</tr>
<tr>
<td>Finding out about journals and conferences to which this work can be submitted; Preparation for the writing of the final PhD thesis and subsequent viva.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Tools and Methods</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathering: SOSIS and other gateways to journals of relevance and working paper. Dedicated search engine for Philosophical research – Hippies</td>
</tr>
<tr>
<td>Communicating: My sosis entry describing the researcher’s interest and calling for interdisciplinary work with Psychologists</td>
</tr>
<tr>
<td>Evaluating: SOSIS and other gateways to journals of relevance and working paper.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Information Plan</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathering: Online resources (course materials, tutorials, CAL-packages) Course materials on the area of research help to form an overview of the research area and the information collected, from selected graduate level course on topics such as the philosophy of science.</td>
</tr>
<tr>
<td>Communicating: Mailing lists, Discussion boards, Newsgroups, table of contents of major</td>
</tr>
<tr>
<td>Evaluating: Local mailing lists on the philosophy and theory of Philos-L mailing run from Liverpool.</td>
</tr>
</tbody>
</table>
### Table: Information Resources and Their Mapping to Toolkit Categories

<table>
<thead>
<tr>
<th>Information Resources</th>
<th>Mapping to Toolkit Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conferences, seminars, Presentations/workshops/lectures</td>
<td>Conferences and event information and call for papers</td>
</tr>
<tr>
<td>Online Journals, books, working papers, etc.</td>
<td>British Society for Philosophy of Science, Royal Institute of Philosophy, Local one day conferences</td>
</tr>
<tr>
<td>Paper-based books, journals, leaflets, etc.</td>
<td>Regular sources include: Syntheses, British Journal of the Philosophy of Science, Working papers found through Hippias, Online book: Probability – the logic of Science</td>
</tr>
<tr>
<td>Search engines</td>
<td>Definitive texts include: Logic of decision, Selling on theories, Philosophy of Science</td>
</tr>
<tr>
<td>Email</td>
<td>Key contacts to whom researcher emails idea – related researchers in the area – both local and international</td>
</tr>
<tr>
<td>Intranet</td>
<td>Members and other postgraduates in the Philosophy department</td>
</tr>
<tr>
<td>Tracking or assessment software</td>
<td></td>
</tr>
<tr>
<td>Databases or data archives</td>
<td>Online catalogues of other universities</td>
</tr>
<tr>
<td>User defined tools and methods</td>
<td>University online journals listing.</td>
</tr>
</tbody>
</table>

Note: the acronyms used in this table are not expanded as it is not the resources themselves that are of interest in this paper, but the concept of the ways in which information resources can be mapped to the information toolkit categories.
8 References


Embedding Theory into Learning Technology Practice with Toolkits

Grainne Conole, Martin Oliver

Abstract:

Expert and theoretical knowledge about the use of learning technology is not always available to practitioners. This paper illustrates one way in which practitioners can be supported in the process of engaging with theory in order to underpin practical applications in the use of learning technologies. This approach involves the design of decision-making resources, defined here as 'toolkits'. This concept is then illustrated with three practical examples. The ways in which this approach embeds specific theoretical assumptions is discussed, and a model for toolkit specification, design and evaluation is described.

Keywords: Frameworks, toolkits, learning technology, practitioners, theory and practice

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Interactive Demonstration:

This article describes the Media Adviser toolkit [www.unl.ac.uk/ltri/demos/demos.htm], and the Evaluation Toolkit [www.ltss.bris.ac.uk/jcalt]
1 Introduction

Learning technology is an inherently multidisciplinary field, and stakeholders include of researchers from different fields (educational research, cognitive psychology, instructional design, computer science, etc) as well as teaching subject-experts who engage with it as ‘end users’ or ‘consumers’. This multi-disciplinarity is a common feature of emergent research areas and, in one sense, is a strength. However, if we are to capitalise on this richness of expertise, it is necessary to work towards a clear theoretical underpinning that allows these diverse cultures to engage with and develop the use of learning technology.

An important starting point for any discussion of this type is the realisation that learning technology use is shaped by contextual factors. Beetham argues, for example, that “Learning technologists have always started from the ‘practical concerns of the classroom’ and we tend to claim validity for our activities according to their impact in the classroom,” and goes on to contend that within this area, “the majority of researchers are concerned to find relationships among the inputs to and outcomes of a learning process which is very poorly theorised, and that this has serious consequences for the future of learning technology research and practice” (Beetham, 2000a). Similarly, Oliver concludes that “an appropriation model of theory use implies that purpose will be determined (at least in part) by situationally specific issues such as the personal background and current needs of its user” (Oliver, 2000).

However, if the use of theory in learning technology is strongly shaped by context, how can academics that are new to this area be supported as they start to engage with it? Is it possible to provide general support and guidance whilst remaining sensitive to the situational influences described above? This paper will explore these issues through one pragmatic approach to applying theory to practice: the development of ‘toolkits’ that support decision making and which are derived from specific theoretical perspectives. The paper will begin with a definition of the term toolkit, along with related concepts (frameworks, wizards and models). Three toolkits will then be described, specifying the theoretical perspective that they draw upon, the methodology behind their development and use, and extracts from evaluation studies of their use with practitioners.

2 The development of strategies for formal reasoning

A range of aids and resources to facilitate decision-making processes has developed to support the use and integration of learning technologies. As a consequence, the terms ‘tools’, ‘toolkits’, ‘frameworks’, ‘good practice’ and ‘model’ abound, but are very rarely used with any consistency. Indeed, there is considerable confusion and overlap within the literature on the precise nature of these types of resources. Therefore, this section attempts to provide some definitions for these terms, along with illustrative examples of the different types of decision-making resource.
2.1 Tools

Any attempt to define ‘tools’ is necessarily broad, so for the purposes of this paper the term is used in the sense of mediating artefacts, drawing on the tradition of Activity Theory (Kuutti, 1997). Within this tradition, tools are artefacts located in a socio-historical context that form an integral part of human action. Such tools may be conceptual or embodied.

2.2 Good Practice

The notion of good practice (or “best practice”, in some uses) is ubiquitous yet ill-defined. Whilst it is usually used to denote guidelines that practitioners are exhorted to follow, this disguises the fact that the term also carries a moral message. Practice can only be judged to be “good” (or otherwise) in relation to a framework of values; thus for this particular paper, we will take “good practice” to denote practice that closely follows the tenets of a given theoretical perspective.

2.3 Models

Models are representations, usually of systems. These are frequently visual representations, although formal models are more likely to be syntactic (or derived from an underlying syntactic representation), often being defined mathematically. Models may be tools, in that they can be used to carry out analyses or may permit certain assumptions to be expressed. Equally, however, they may be the object (i.e. purpose) of an activity, in that it may be necessary to construct a model of a system in order to develop an explicit understanding of how it works.

2.4 Frameworks

Aids to decision-making range from highly restrictive ‘templates’ or ‘wizards’, which provide high levels of support and step-by-step guidance but little possibility of user-adaptation, through to ‘theoretical frameworks’, which provide a context and scope for the work but leave the user to devise their own strategy for implementation.

2.5 Templates and Wizards

By way of a contrast to theoretical frameworks, another approach to supporting the use of learning technology involves the use of highly structured decision-making systems: templates and wizards. Generic templates are found in most software
packages. They can provide structured, pre-defined layouts or structures for the user to base their document or presentation on. A wizard is a software tool that makes decisions on behalf of the user, based on solicited information and drawing on pre-defined templates. In most cases, the way in which these outputs are generated is hidden from the user. As a result, wizards and templates are relatively easy to use, but are restrictive in the range of outputs that can be achieved, and allow very little engagement with issues or response to the values and assumptions built into the system. There are many examples of templates and wizards that provide a generic structure that guides users through a set of options. Online shopping sites, book stores and travel centres often have ‘wizards’ which guide the user through a series of options or interests, helping them to focus in on topics of particular interest. It is evident that these types of semi-structured forms of support and guidance are becoming increasingly important as a way of guiding users through the plethora of information available online.

### 2.6 Frameworks

In contrast to the highly restrictive ‘templates’ or ‘wizards’, which provide high levels of support and step-by-step guidance but little possibility of user-adaptation, stand frameworks, which provide a theoretical context and scope for work but leave the user to devise their own strategy for its implementation.

Within this context, a number of pedagogic frameworks have been developed to support learning technology. All develop from a particular theoretical viewpoint (whether explicitly or implicitly), aiming to encourage the application of good practice according to a specific pedagogical approach. For example, Conole and Oliver (1998) have developed a framework for integrating learning technologies that builds on Laurillard’s conversational framework. This provides a structured approach to integrating learning materials into courses. The framework is designed to support the process of ‘re-engineering’ a course (Nikolova & Collis, 1998). It provides a framework in which various features of an existing course can be described and evaluated, allowing an analysis of strengths and weaknesses, the suitability of different media types (in particular the different educational interactions they support) and limiting factors, including resource issues and local constraints. The framework can be applied as a series of stages, starting with the review of existing provision, working through a process of shortlisting and selection of alternative teaching techniques, and concluding with a mapping of the new course.
2.7 The relationship between Frameworks and Wizards

Frameworks and wizards, as outlined above, both share a common aim of supporting a users’ engagement with an area. Clearly, however, they are working at very different levels and making different assumptions about the type of support that the user might need. Theoretical frameworks provide a structure and vocabulary that support the exploration of concepts and issues. Wizards provide automated processes that support the production or selection of resources, and are predicated on the assumption that the user is primarily concerned with efficiency rather than critical engagement. Fundamental concerns (for example, about the suitability of using a particular type of resource) are either ignored or assumed by the wizards.

These two positions can be characterised as extremes of one continuum. At one extreme there are frameworks, which are flexible and versatile, but which offer relatively little support for practitioners attempting to engage with them. At the other there are wizards and templates, which are highly restrictive, but (by virtue of the constraints that they impose) are able to offer much closer support and guidance to users.

Between these extremes lie a range of resources, including checklists, guidelines and step-by-step tutorials. Toolkits can be viewed as a mid-point on this continuum: they are decision-making systems based on expert models (Oliver and Conole, 1999). (In this context, a model is taken to be a simplified account of reality that can be used to explain or predict certain features. In toolkits, models tend to be of design processes.) Toolkits are more structured than frameworks; they use a model of a design or decision-making process, together with tools provided at key decision-making points, to help the user engage with a theoretical framework and apply it in the context of their own practice. Each of the tools that is drawn upon as the user works through the process model is designed to help the user to access a knowledge base in order to make informed decisions. The format of toolkits means that they can be used in a standard, linear fashion, or can be “dipped into” by users whose level of expertise is stronger in some areas of the design process than others.

In summary, toolkits represent a mid-point between facilitated, uncritical development of resources and a deep engagement with fundamental issues and theories. They are not intended to replace expertise, although they are intended to reduce the need for prior expertise before practitioners are able to engage with fundamental issues in a meaningful way. As such, they can be viewed as a stepping-stone between uncritical and autonomously critical engagement with an area.
2.8 Are toolkits expert systems?

From the discussion of earlier drafts of this paper, it became clear just how closely toolkits were related to expert systems. The close relationship arises from the shared aim of both types of resource to encapsulate methods and theory within a software tool. In addition, it is recognised that both types of resource embodies "claims" about the world that can be reverse-engineered through claims analysis. What, then, is it that makes it appropriate to differentiate between these types of intelligent design aids?

Toolkits and expert systems differ in four important respects. Firstly, unlike most expert systems, the emphasis with a toolkit is not on providing answers or knowledge in response to a query. Instead, the focus is on modelling the user's practice. The creation and analysis of these models then forms the basis for the creation of plans, knowledge and understanding that is directly related to the user's context and cultural practices. (Importantly, the modelling of practice here is carried out by the user; it is not a model of the user created by the system.)

Toolkits are designed to address multiple distinct areas of knowledge, and in many ways the "tools" (in the sense given above, but here also alluding to the specific elements that are combined to make up a toolkit) designed for some of these areas could be described as being like expert systems, to the extent that some of them make recommendations based on a representation of an underlying knowledge base. However, we argue that one important defining feature of toolkits is the relationship between these modular elements – the focus is on the sustained engagement, by the user, in order to draw together a string of such advice, rather than on one output generated by the system and presented to the user.

Another important distinction is that toolkits do not embody a claim to "expertise". Instead, their claims are far more tentative. Rather than attempting to be authoritative or definitive, toolkits are predicated on the basis of utility. Specifically, they are judged on how useful the system of classification used to represent the underlying knowledge base is in terms of supporting decision making. This represents an important move away from legitimation in terms of meta-narratives and towards a performative definition of value (Lyotard, 1979). However, unlike many other forms of commodified knowledge, it is the user, not the designer, who decides on the legitimacy of the representation. The descriptive systems, the frameworks drawn upon in the toolkit, simply act as a starting point that can be debated, adapted, revised and so on. Thus instead of being expert systems, they might more accurately be called "amateurs’" systems.
The plurality of that last point leads on to the fourth important distinction between expert systems and toolkits. Toolkits are about each user’s domain, rather than one idealised domain. The framework and knowledge base provide a way of describing what users do in some area of practice – hence the link made to modelling, above. The knowledge base described at each step can, and we argue should, be altered by the user to reflect their own (rather than some idealised general) practice. Moreover, toolkits are designed so that each knowledge domain described can be extended, as well as amended, by the users. The implication of this is that toolkits cannot be expert systems as traditionally understood, although with sustained use, an individual users’ adapted instance of a toolkit might conceivably be described as an expert model of their own practice.

Essentially, then, we see toolkits as having a new niche in terms of modelling end user expertise. Unlike expert systems, which present themselves as authoritative and definitive, toolkits adopt a more postmodern position on the problems of practice, celebrating difference, contextuality and a democratic form of interaction that allows the user to create and direct instead of being directed. In this sense, they are perhaps best located as a means of representing and sharing practice, rather than a way of privately receiving advice on one’s own practice (cf. Beetham, 2002).

Importantly, this modelling of experience an interative process, which may (but does not always) start from an initial, general given model (a “starter for 10”) of the domain. This gives rise to a fifth distinguishing feature of toolkits, which arises as a corollary from the above points: that unlike systems which take a static snapshot of expertise, toolkits evolve (and reflect the users’ evolving understanding of the domain as they do so).

### 2.9 The epistemology of toolkits

As the above discussion has begun to demonstrate, the distinction between toolkits and other kinds of decision support tools has its roots in a distinctive epistemological position. Whereas expert systems present an authoritative model of a particular realm of knowledge, toolkits are concerned with personal, contextual and often fragmented representations.

From discussions on an earlier draft of this article, it became necessary to clarify the ‘classes’ of knowledge toolkits are concerned with. When working with toolkits, there are two types of knowledge we are interested in – and more specifically, are interested in transforming:
1. Theoretical knowledge, such as models, frameworks, and so on. Here, we are concerned with the transformation of these forms of knowledge as ‘given’, being legitimated by their acceptance within expert communities, into performative kinds of knowledge (such as a system) that can help guide the user towards particular things (methods, tools, etc.) that would be of use.

2. The tacit knowledge essential to professional practice (McMahon, 2000). Here, we are interested in making this knowledge explicit (or, more accurately, helping practitioners to make their own knowledge explicit). This is achieved by the elicitation of users’ own practices as part of their use of the tool. This elicitation may be achieved syntactically; however, at other times, it involves the construction of visual or multimodal representations (see the Appendix for an example of this), echoing the new forms of scholarly discourse and rhetoric discussed by Ingraham (2000).

The latter in particular is novel in the context of decision support tools. Traditionally, most expert systems have been restricted to formalised, well-defined areas of knowledge that can be represented in relatively stable, conventional ways. However, it is in the context of the situated, ill-defined, poorly understood areas of tacit knowledge about professional practice that toolkits demonstrate their value – and this is perhaps their key benefits. The reason toolkits are so interesting is because they are able to extend the range of existing decision support tools beyond the individual instances of stable knowledge in well defined areas and out into the murky waters of professional practice. This is achieved by putting the provisional nature of models centre-stage, allowing them to be adapted and refined in the light of users’ beliefs and local situations, and also by emphasising that users should describe their own (situated) practice rather than attempting to work with an externally-imposed ‘ideal’ model. It also emphasises the importance of viewing toolkits as representations to be contested, of drawing the users’ attention to their rhetorical and constituting effect, so that they may debate, refine or replace the models that are used to reflect their practices.

There are, inevitably, limits on the kinds of knowledge that are appropriate to address toolkits. The kind of codification envisaged thus far concentrates on design and decision making, and we suspect that this may well represent the appropriate scope for tools of this type.
A rationale for toolkits

In recent years, nationally policy has placed a considerable emphasis on the embedding of new technology into the learning and teaching process. However, the embedding process is not trivial, and uptake has traditionally been patchy (Laurillard, Swift and Darby, 1993). One reason for this is the considerable range of skills that need to be acquired if embedding is to be carried out in a professional way (Phelps, Oliver, Bailey and Jenkins, 1999; Beetham, 2000b).

Despite the current policies which advocate that adapting and re-using existing learning materials and a more extensive use of learning technologies to support learning and teaching is a good thing (e.g. the Dearing report, National Committee of Inquiry into Higher Education, 1997), examples of this are few and far between. This can be traced to a number of factors. In particular, the ‘not invented here’ syndrome (HEFCE, 1996) is no doubt still present. However, more important perhaps is the issue of the time and skills required to evaluate and then adapt materials or gain expertise in understanding and utilising learning technologies. The latter is compounded by the fact that finding these materials in the first place is a non-trivial exercise (although the growth of subject-specific information gateways, portals and guidelines to resources will go some way towards alleviating this problem). Some of the barriers to uptake which have been identified include: the problem of finding relevant materials in the first place, the difficulty of adapting other peoples’ materials, the issue of ownership and copyright, integration with other materials, including issues of style, definition and level, staff having the appropriate educational and/or technical skills required to evaluate, adapt and integrate materials, and concern about the currency of materials, particularly accuracy and whether it is up-to-date (Conole, Oliver and Harvey, 2000).

Equally significant is the problem that large amounts of research and theory on the use of such resources remains unfamiliar to practitioners. Whilst it would be unreasonable to expect subject specialists to dedicate themselves to the study of and engagement with this area, problems can arise when these people begin to adopt learning technology. In such situations, it is important to consider how these practitioners can best be supported, and whether that support should focus on addressing basic needs (such as efficient production, suggesting the need for tools such as wizards) or should encourage them to engage at a deeper level. The continuum of support outlined earlier suggests that one solution to this problem may be to provide a series of steps, through which support is steadily phased out whilst flexibility and versatility is introduced. Toolkits are intended to act as a mid-point in this transitional process, allowing greater engagement than wizards and templates can, but providing more structure and support than a theoretical framework.

Another important feature of toolkits concerns the decision-making activities that the user can
engage with whilst following the expert model. As noted, these are intended to support the user in the process of making informed decisions; they rely on a structured description of a relevant knowledge base that can be automatically searched (based on information elicited from the user) in order to suggest approaches that might be relevant. By layering progressively more detailed information on the options available, the user is able to follow up when and if this is required. For example, if presented with a shortlist of suggested methods, a user might immediately be able to reject familiar and unsuitable options simply from their title. Unfamiliar options might require short explanatory or illustrative information before they could be accepted or rejected, and some might warrant detailed discussions (perhaps including illustrative case studies). Because this simple layered structure presents information ‘on demand’, rather than expecting the user to wade through tracts of material that may or may not be relevant, they are quicker and easier to use than handbooks, cookbooks or other traditional sources of advice and guidance. The implication of this is that toolkits should help to reduce the time required in planning work of this type. The aspiration is that toolkits can be used iteratively, with progressively more detailed analysis occurring once initial feedback about the viability of the initial design has been received.

In summary, toolkits are predicated on the assumptions that they will be:

- derived from an explicit theoretical framework
- easy-to-use for practitioners
- able to provide demonstrable benefit
- able to provide guidance, without being prescriptive
- adaptable to reflect the user’s practice and beliefs
- able to produce outputs that reflect the local context

4 The development and evaluation of toolkits

The process of the development of each toolkit consists of a number of steps, which are can be coached in terms of framing questions.

4.1 Assessment of need: Is there a need for a toolkit in this particular area to support practitioners?

All three of the toolkits outlined below fit this criterion. Learning technologies have impacted significantly in the areas of curriculum design, evaluation and information handling. Their introduction has added a degree of complication and new forms of expertise to the extent that practitioners need support and guidance, which is a fundamental component of the toolkits. With respect to curriculum design, for
example, key issues for practitioners include making sense of the range of learning technologies which can be used to support learning and teaching receiving guidance on how to integrate these effectively with traditional tools and techniques. A lack of understanding of the precise impact of learning technologies, a better knowledge of their strengths and weaknesses, and some understanding of potential costs and benefits, are some of the evaluation topics which practitioners now need to address. In terms of information handling, the sheer enormity of scale of the resources and information available now, along with the increasingly sophisticated online information tools, gateways and portals, means that practitioners also now need some guidance on and understanding of how to utilise this.

4.2 Theoretical underpinning: What theory and models are relevant to the toolkit?

This step makes explicit the underlying theory and expert model to be used by the toolkit, providing a frame of reference and an initial structure for decision making.

4.3 Toolkit specification: How can the range of options available at each stage be translated into a practical but flexible form of guidance for non-experts?

A rough outline of the toolkit is drawn up, based on the framework, which will include the description and structuring of the options (knowledge base) open to users at each decision making step. The toolkits are designed to be easy-to-use, with information structured in layers of increasingly detailed material so as to support flexible use, allowing users to bypass sections with little or no relevance to them or engage deeply with content that they find important.

4.4 Toolkit refinement: How useful and flexible is the toolkit?

At this stage, a prototype of the toolkit is tested with end users and evaluated to assess its suitability, ease of use, flexibility and relevance. In particular, feedback from this formative evaluation stage is used to highlight which aspects of the toolkit the users find most useful, and whether there are any important steps or resources omitted. This information is used to iteratively improve the toolkit and provide a more detailed specification. Considerable attention is given to the users’ needs, particularly how easy the toolkit is to use and how valuable and useful it is perceived to be. User trials also aim to demonstrate that the toolkit is usable without the
support of expert guidance, which represents an important part of the initial assumptions behind the development of toolkits.

4.5 **Inclusion of user defined features: Is the toolkit sufficiently flexible that it can be adapted by end users to take account of local factors?**

User trials also assess the flexibility of the toolkit to take account of adaptation by end users. Identification of common adaptations, which are likely to be of wider value, can be incorporated into the core functionality of the toolkit at this stage.

4.6 **Building shared resources: Are the completed toolkit plans produced by practitioners of any value as case studies or templates for other users?**

Use of each toolkit produces some form of 'plan' for a particular task; for example an evaluation strategy to assess a range of web resources, an outline for a new curriculum with a map of learning and teaching tools and techniques, or an information plan for resources for a research project. The user can keep this private, perhaps iteratively refining it over time based on experience or developing understandings. However there are potentially a number of additional uses for the plan. It could be used as one of a suite of shared resources, for example a set of curriculum plans for a whole course, evaluation strategies for commonly encountered evaluation studies, or information resources to support a consortium-based research project. This is a valuable additional aspect of the toolkits and provides a means of addressing some of issues about re-purposing materials and sharing skills sets outlined by Phelps et al. (1999) and Beetham (2002).

5 **Illustrative toolkits**

This section will illustrate three examples of toolkits that have been developed and tested using the process outlined above. Key findings from the formative evaluations of these toolkits will be summarised and perceived benefits identified.

5.1 **A toolkit for curriculum design**

Media Adviser (http://www.unl.ac.uk/ltri/demos/demos.htm) is a toolkit that can support practitioners redesigning curricula and, in particular, helps them to consider how to appropriately integrated learning technologies alongside more traditional...
learning and teaching methods. It derives from a broader conceptual pedagogical framework for integrating learning technologies into courses that maps out and compares traditional modes of delivery with learning technologies (Conole and Oliver, 1998; Oliver and Conole, 2000). It considers different learning and teaching methods in terms of their relevance and value against a set of four types of teaching activity, namely – delivery, discussion, activity and feedback. These four activities were adapted from the more descriptive set of twelve interactions described in Laurillard’s conversational model (Laurillard, 1993), and are intended to reflect the values of the socio-constructivist tradition that she draws upon. In addition to its role in providing support for curriculum re-design, the toolkit has been used successfully to engage practitioners in discussions about their own context and practice – for example, by encouraging a group of practitioners to debate the relevance and meaning of the four ‘types’ of teaching activity, whether or not refinements or adaptations of this set are warranted, and how these activities might be perceived by learners (Oliver & Conole, 2002).

This was the first toolkit developed using the methodology outlined above. As the explanation below illustrates, the formative evaluation of an initial prototype combined with a process of iterative tailoring to meet users’ needs is an important feature of this approach. The evaluation also generated a number of unexpected results. In particular, mapping teaching techniques (both traditional and new) in terms of their support for the four ‘types’ described above was originally intended as a way of identifying aspects of learning that were systematically emphasised or neglected in a course. However, evaluation showed this was at least as important as a way for individuals to express their own approach to teaching, or to develop ideas about new ways in which traditional resources (such as videos) could be incorporated into the course. Moreover, the simplicity of the description meant that it could be used as the starting point for comparisons or discussions between practitioners about the differences in their approach to teaching.

What was important with this toolkit was that it raised awareness of the potential uses of learning technologies, in particular in terms of educational value, and therefore formed a good starting point in terms of considering the role of these resources within a particular course. The toolkit was then used to aggregate these individual descriptions of techniques in order to form a more holistic course structure. Media Adviser provides a mechanism to help lecturers think about the different tools and techniques they could use in their teaching and most importantly how these could be considered under the four broad educational activities.
5.2 **A toolkit for evaluation**

The Evaluation Toolkit (http://www.ltss.bris.ac.uk/jcalt/) provides a structured resource to help practitioners evaluate a range of learning resources and activities (Conole, Crewe, Oliver, and Harvey, 2001; Oliver, McBean, Conole and Harvey, 2002). It guides them through the scoping, planning, implementation, analysis and reporting of an evaluation. It assists the practitioner in designing progressively more detailed evaluations, and allows users to access and share evaluation case studies. It consists of three sections: Planner, Adviser and Presenter, which guide the user through the evaluation process; from the initial scoping of the evaluation question(s) and associated stakeholders, through selection of data capture and analysis methods, and finally through the presentation of the findings. One of the emerging benefits of this toolkit is that the plan the user produces can be made available to other as a case study or example for particular types of evaluation (e.g. assessing the usability of a web site, research a teaching innovation, selecting a set of resources).

5.3 **A toolkit for information processing**

The information toolkit adopts a similar approach to Media Adviser and the Evaluation Toolkit (Conole, 2002). It provides a means of mapping information resources against types of information activity (defined in the toolkit as gathering, processing, communicating and evaluating). This helps the user to gain an understanding of the resources they are using and what they are using them for, to help them produce their own tailored information plan. The toolkit guides the user through the process of articulating their information needs and results in the production of an information plan for a particular task. The ‘scope’ of the task is one of the first stages of working through the toolkit; a task could involve considering all the information needs of a course team developing a course module, of managers of a research programme or a development project team. As with both Media Adviser and the Evaluation Toolkit, this can be used to build shared information plans in the form of case studies or templates. It is suitable for use across a range of levels of expertise and valuable for both learners and researchers.

6 **Evaluation of the toolkits**

The evaluation of the toolkits was designed to provide feedback on the usability of toolkits and to assess their potential impact on practice. The methodology used includes observational studies and a follow up workshop with new users (Oliver, MacBean, Conole & Harvey, 2002). In the initial stage, usability trials in the form
of cognitive walkthroughs are carried out. These are used to improve the design and layout of a toolkit and to help the content developers to identify areas that required further work and improvement. In each case a researcher observes and records the user’s activities. At the end of a session users also provide feedback on the overall use and value of a toolkit, areas for improvement, and whether format of a toolkit had influenced the way in which they had approached their planning process. Overall, this process of evaluation is used to address two fundamental questions: does the toolkit support the design of appropriate plans (“appropriate” as determined by the user), and does it help the user to engage with some of the more fundamental issues and concerns in this area?

Feedback from these trials is used to improve the toolkits and in particular the overall structure and navigation of the resources. Once an updated version of a toolkit had been produced, taking into account all the feedback from the initial usability trails, the second phase of the evaluation is carried out. This takes the form of one or more workshops comprising a range of potential users (e.g. lecturers, managers, researchers, and staff in university support services or national centres). During these one-day workshops, the participants work through a toolkit section by section. They are asked to keep a record of their activities and in particular to note any reflections as well as any benefits or problems encountered. At appropriate points the group is drawn together to discuss progress and in particular good and bad features of the toolkit. The workshops conclude with a general discussion of their experiences of using the toolkit and its potential value and use.

Early feedback on the toolkits in these evaluation stages tends to concentrate on usability issues and navigation. Users are often frustrated by the early navigational structure and layout of the toolkits, which can fundamentally impede their progress and hamper their understanding of the issues and concepts being described. In each case, the toolkit is refined in light of such comments, with the result that the usability is markedly improved by the end of the project.

In order to demonstrate the evaluation approach, and also to illustrate the kinds of ways in which users were able to engage with theory, two studies will be summarised – one involving the evaluation toolkit (Oliver, MacBean, Conole & Harvey, 2002), the other Media Adviser (Oliver & Conole, 2002).

6.1 Evaluation of the Evaluation Toolkit

Feedback on the content and potential usefulness of the toolkits has generally been
positive. Users clearly benefit from working through them and recognised that they were rich resources of material. However, there was some concern that the Evaluation Toolkit was deceptive in terms of its size and ease of use. (The toolkit comprised of three sections, each of which took around an hour and half.) In general it was recommended that users should be made more clearly aware of the time required to complete each toolkit and the level of detail and concentration required if the user were to gain optimal value from using the resources. It was encouraging to note that the improvements made to the toolkit as the result of initial feedback are noticeable in the way that the workshop users work through the resources much more easily.

Reassuringly, however, the toolkit was able to support complete novices.

*Well, to be honest, I haven’t had to produce an evaluation plan ever before – so in that sense it was extremely helpful as it guided me through the process, explained some background ideas and suggested other sources of help.*

It also proved to be of value to evaluators who had substantial previous experience.

*Did it get me thinking about other things? Yeah it did actually because I was looking at a project we’ve already done and I ended up looking at analysis tools I wasn’t familiar with, so that was useful.*

Perhaps most encouraging was evidence that the toolkits encouraged reflective practice:

*I really liked [it] making me think about the purposes of evaluation. I’ve completely changed my view of the evaluation by working through this.*

Particular theoretical ideas were also engaged with by the participants. For example, Patton’s utilization-focus approach (1997) conceives of evaluation as being an essentially rhetorical process, in which studies (and the way they are reported) serve political, use-based ends; by working with the toolkit, users’ traditional practices were challenged by this theoretical perspective.

*The emphasis on ‘contexts’ and reasons for evaluation throughout the toolkit is very helpful, because there is perhaps a tendency to report what was done on a particular project (as a factual account of what happened) rather than actually evaluating that project and how useful its outcomes are to the stakeholders. The toolkit seems to bring the user back to this point all the time – which would be very helpful, particularly in a big project, or one with lots of interested parties.*

Journal of Interactive Media in Education, 2002 (8)
Further related to this is the issue of choosing the evaluation question, which theorists such as Kvale (1996) link explicitly to questions of epistemology. 

*I tried to fill in every box but I actually found that quite useful because it forced me to think about things that I wouldn’t have otherwise.*

There were, however, some limits on willingness to engage with such theoretical positions. For example, the evaluation toolkit is designed to recommend particular methods for data collection and analysis based on the question asked. This is achieved by filtering the methods using the (editable) representations of the knowledge base on data collection and analysis methods. In this particular case, the rationale for selection was not apparent to the users, some of whom failed to see why particular empirical approaches followed from their stated perspectives on the world:

*To be honest I just filled in my favourites. I didn’t understand how it had come to those conclusions and I didn’t agree with them. So I ended up just calling up the entire list and just selecting the ones I was going to use anyway.*

The reasons for these objections were also discussed by the participants.

*You have a preconceived idea and you’re expecting something. You get frustrated when you didn’t expect what you get.*

*I think that some people don’t like things being hidden from them. They can see your suggestions, but they also want to see the rest.*

Whilst the toolkit did support engagement with theory, then, it cannot require users to engage. Nonetheless, it is able to prompt the kind of reflection and engagement predicted earlier in this article.

*What’s really important is that it gets you to think about all this.*

*Clearly it’s something we’re all having to do more of. We’re all having to reflect on what we’re doing.*

*If it doesn’t quite match what you were looking for at least it makes you think.*
6.2 Evaluation of Media Adviser

A small-scale study with Media Adviser was carried out that involved three users, two drawn from one course team and one drawn from a different faculty. Each had experience of teaching on a number of courses, but had chosen one course that they felt needed changing. The jointly-taught course was a first-year unit in a medical programme, taken by around 120 students, roughly three quarters of whom were taking the course as part of a subsidiary subject. The other course was also a first year course, but was about economics, and involved a mix of historical review and case studies. It is taken by around twenty students, half from within the economics department, and half from the faculty of social sciences. This mix allowed differences in practice both within and between faculties to be illustrated. The workshop was run by one facilitator, with an additional observer taking notes and helping out when required.

Even from the first activity – which simply involved listing the teaching methods used during the course – participants started to reflect on fundamental issues of course design, such as the difference between a teacher-centred and a student-centred description of the course.

Are these teaching or learning media?

Similarly, there was reflection on the fact that “different groups of students might have different experiences of our lectures”, showing the influence of theoretical perspectives such as phenomenography. They also distinguished between their intentions and the reality of what might actually happen, showing sensitivity to the limitations of a modelling exercise such as this:

Not so easy to determine - was there any discussion? - but can’t force this from students; [it] may happen or may not (i.e. no guarantee that will get discussion or how much).

As with the Evaluation Toolkit, engagement with the software (particularly in this group context) led the lecturers to challenge their previously taken-for-granted course design practices, which they came to realise reflected tradition rather than any explicit theory of learning. This discussion drew on the earlier consideration of student-centred rather than teacher-centred models of course design, emphasising the values that they felt were central to their practice.
It makes you reflect on what... are possible for the student. Often one feels the number of lectures, tutorials etc. is given and immutable. It's useful to see how the course breakdown looks.

The second activity, which involved using the rater tool to describe their teaching, led to further questioning of the role of different educational techniques. On discovering that he had characterised lectures and handouts in an identical way, one participant began to wonder, “Why not replace lectures with handouts?” This led to a rich discussion of student expectations and institutional policies, raising participants’ awareness of the marketing and political aspects of course design. It also highlighted the way in which familiar formats can appear to be engaging without actually involving the student in anything more than a passive, receptive role.

Students seem to want to feel that they have participated, and somehow, by sitting through a lecture, they think they have done.

The descriptive process also highlighted differences in teaching style. For example, one participant characterised their lectures as involving a high degree of activity and discussion for students; this contrasted with the two lecturers who both taught as part of one course team, for whom lectures were primarily a means of disseminating information to students. Similarly, all three had differing views about what constituted a tutorial. Importantly, there were differences between the two members of the course team that had not previously been recognised. This led to a discussion of how each participant ran their tutorials, and an exchange of suggestions about how they could be made more interactive and engaging. As one participant noted, such discussions provided obvious opportunities to extend lecturers’ repertoire of techniques by learning about “the different ways in which people use handouts, tutorials, lectures, etc.” The result of this was the early sharing of plans for change that were grounded in participants’ own experiences.

As part of these discussions, the participants began to identify reasons why teaching techniques such as lectures differed. ‘Disciplinary differences’ were initially cited as one possible reason, but the existence of differences within the course team led to a more critical discussion of what this phrase might actually mean. Eventually, a number of influences were identified, each of which contributed to the process of determining the format of teaching, including:

- Whether the teacher has a teacher-centred or student-centred view of learning.
• Current trends in learning and teaching. (“If we’d done these ten years ago, the differences between us might have been much narrower.”)

• The status of knowledge and the type of discourse within a discipline. (“In arts, if a department came out where delivery [of information] was high there would be something very wrong”; “in science, there is a mass of basic information you need to have, whereas in History, it is different – it doesn’t matter if you know nothing about the 19th century.”)

• The content covered in the course.

• The level of students being taught. (“For first years, the emphasis is on the delivery of information. Further on, they are expected to discuss rather than receive, so most lectures will change.”)

• The size of group being taught.

• Student expectations and requirements. (For example, are they intrinsically or extrinsically motivated by the course?)

• What other teaching techniques are used in the course.

In recognition of these influences, the participants recognised that there would never be agreement as to the ‘right’ way to describe a lecture, tutorial, etc. (This illustrates the points made about toolkits and multiple perspectives in earlier sections.) However, they felt that descriptions of techniques would “start off differently, but might converge” as users of the toolkit debated their understanding of the descriptive language and reached consensus over the meanings of terms.

In a similar vein, the participants discussed whether or not to introduce less familiar techniques, such as web-based teaching, computer-mediated communication, and so on. Importantly, there was valuable discussion about what these terms meant to the participants, and what role they might have in teaching and learning. One participant, for example, decided that what he meant by ‘web pages’ conflated at least two distinct activities – the use of the web to deliver lecture notes, and the use of online bulletin boards to supplement class discussions. This clarification enabled him to plan changes to his course in greater detail, concentrating on pedagogic requirements rather than the technical systems available to him.
Given the comments made earlier about the potential value of toolkits for sharing representations of practice, it is interesting to note that participants in this study saw this as being valuable not only within a network of peers, but also as a way of communicating conceptions of learning and teaching to students.

The other area – and perhaps the more useful one – is to display it to students... Giving them this information will enable them to make judgements about what you as a lecturer are doing.

7 Conclusion

Although there is broad consensus that practitioners value some kind of support when starting to use learning technology, the most appropriate way of providing this support remains unclear. One factor that will influence this will be the relative importance that specific practitioners place on engaging with theory as opposed to simply producing resources in an efficient way. At present, the kind of resources that have been produced tend to be polarized between flexible but unsupportive frameworks on the one hand and supportive but constrained wizards and templates on the other. The work described in this paper has investigated the design and implementation of a form of expert system to support decision-making processing, defined here as toolkits, which can be viewed as a mid-point between these extremes.

This work has provided a definition of ‘toolkits’, which incorporate an expert model of a process and structured knowledge base. The toolkits described in this paper illustrate the ways in which support and guidance on theory and expert knowledge can be provided to practitioners in a way that can be interpreted in light of their disciplinary context and individual practices.

Feedback has been positive, with many users reporting that the toolkits helped them to reflect upon and structure their thought process. Other benefits identified include:

- The ability to build up case studies covering common types of curriculum design, evaluation, or information maps.

- Provision of structured expertise and a resource base, built on an explicit theoretical basis, which guides the user through the planning process and uses this experience to help them engage with the theory and related knowledge themselves.
• The potential to carry out additional studies with a more diverse group of users to analyse the different ways in which these resources can be used and a clearer understanding of their benefits. Feedback from this type of study could be used to improve the value and relevance of the toolkit itself and also help define the key factors for success in producing toolkits and hence help define specifications for future related resources of this kind.

• The potential to extend this model of developing generic toolkits to cover other areas of learning and teaching such as curriculum development, media selection, assessment or quality assurance.

Whether the mid-point represented by toolkits should be viewed as an end in itself, or as a step between facilitated production and critical engagement remains open to debate. However, early use of these resources to support both of these ends is encouraging. However, to extend this approach to new areas will require the identification or development of theories for learning technology coupled with the application of rigorous research methods; without this, toolkits will not be able to offer anything more than platitudes and surface guidance.

8 References


9 Appendix: A use case to illustrate Media Adviser

This appendix is intended to illustrate one of the toolkits described in this paper – Media Adviser, which is an instantiation of the pedagogic toolkit. (The toolkit is available to download from http://www.unl.ac.uk/ltri/demos/demos.htm.) One application of the Media Adviser is in support of quality assurance procedures, many of which are founded on the principle of making tacit practices explicit. In the context of quality assurance, Media Adviser serves a particular role in relation to the introduction of new approaches to learning and teaching, such as the use of web-based materials or discussion areas. It has been shown, for example (Kewell et al., 1999), that practitioners find it hard to:

• articulate the suitability or relative merits of, say, web pages over lectures;
• assess the suitability of unfamiliar teaching techniques (with most practitioners, Learning Technologies provide a vivid illustration of this);
• agree on the meaning of common terms such as “lecture”; or
• gain an overview of the suitability of a mix of teaching techniques.

The process of describing and modelling required by Media Adviser allows implicit assumptions and tacit knowledge to be represented and used as the basis for decision making. It also provides a shared form of representation that enables practitioners with differing assumptions to identify and discuss the variations in their practice.

The first step towards this consists simply of entering basic information about the course such as its title and learning objectives. This elicitation is mainly for record purposes, and is not shown here. The next step (Figure 1) involves use of a tool that requires practitioners to describe and compare their teaching strategies in terms of a recognised educational model (Laurillard’s conversational framework; Laurillard, 1999).
After this descriptive process, a linked tool, the Course Modeller (Figure 2), allows models of courses to be created by specifying how many hours students are expected to spend experiencing each teaching technique. These models can then be compared, and the suitability of different combinations of teaching techniques can be judged in terms of their impact on the way time is used within the course.
On the basis of these models, a third tool can be used to allow practitioners to assess the likely cost (in terms of cash, time to prepare and time to sustain the approach). This tool is called Media Selector (Figure 3); it consists simply of a customisable card file system describing features of various learning and teaching approaches.
A typical use-case for this tool might be for an individual lecturer considering the redesign of their course, perhaps to include the use of the web. Starting from a description of their current practice, and a model of their current course, they might then introduce new forms of learning and teaching and experiment with the range of models that could result. These models could be discussed with colleagues, who might challenge the way existing practices are described or offer new ways of conceiving of the use of the web. Once consensus has been reached about one or two desirable models, the media selector tool could be used to assess the likely cost of these changes in terms of time and money. This might include a simple move from the current situation to some ‘ideal’ model, or it might involve working in the short term to some mid-point between the two due to limitations of time, expertise or resources.