Implementing Courseware to Support Learning Through Real-World Erroneous Examples: Students' Perceptions of Tertiary Courseware and Obstacles to Implementing Effective Delivery Through VLE

Rachada Monthienvichienchai[1] and Erica Melis[2]
[1]London Knowledge Lab, Institute of Education, UK
[2]German Research Center for Artificial Intelligence, Germany
P.Monthien@ioe.ac.uk
melis@dfki.de

Abstract: This paper presents a study in a UK university that investigated how first-year (freshman) Information Systems undergraduates perceive learning through courseware containing real-world erroneous examples derived from their peers and what obstacles had to be overcome to implement effective e-Learning support for using and creating such courseware. The study finds that students find the courseware very effective in dealing with their personal misconceptions while also providing other secondary pedagogic benefits for both students and lecturers.

Keywords: courseware, vicarious learning, and personalisation

1. Introduction

Erroneous examples have often been used in many subjects to prevent students making common mistakes in a particular domain; for example, calculus in mathematics and systems design in computer science. However, such examples are often only loosely related to the actual difficulties and causes of misconceptions that the students may actually have with the domain. Consequently, often to the surprise of the lecturer or tutor, students still make errors that are related to erroneous examples already given to them. A possible solution for this is, to use as examples, errors that actually came from the student population themselves or another student population that has similar characteristics to the target student population. Such examples, compared with those from other sources, would be more grounded in the experience of the students. e-Learning courseware (online learning material) that delivers teaching through real-world erroneous examples, if effectively implemented, may have a distinct advantage over traditional learning material in that it enables the students to vicariously experience through rich media how the errors were made and how they can be effectively corrected. However, some outstanding questions remain concerning effective implementation of such courseware; in particular, how would students react to learning from courseware that uses errors instead of the usual 'perfect answers' and whether their reactions can help to improve future courseware design?

2. Current use of erroneous examples in mathematics

The behaviourist view of learning that informs much of traditional schooling is not likely to invite students and teachers to see errors in a positive light. Behaviourism assumes that learning is enhanced when correct responses are rewarded (positive reinforcement) and incorrect ones are either punished or extinguished through lack of attention (withholding of positive reinforcement) (Miller 1983).

As opposed to learning and teaching of language and programming, most of today's mathematics teaching still follows the traditional approach and tries to exclude error-making at all costs even at the cost of reducing learning opportunities.

Within the traditional framework, paying explicit attention to (mathematical) errors in class is even considered by many as dangerous since it could interfere with fixing the correct result in the student's mind. However, our approaches use errors as learning opportunities and they may help to overcome the traditional transmission view of mathematics (and computer science) teaching and learning.

Indeed, the effectiveness of different ways to use errors as a springboard for learning is a question that has to be investigated empirically. Additionally, whether the effect can be different for different types of learners is an open issue and may depend on the specific individual learner characteristics.

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Previous research have indicated that including erroneous learning objects into a learning experience can serve several purposes:

1. Improvement of learner's motivation (Strecker 1999) and influence on students' attitudes towards failure and success.
2. Proper understanding of concepts, which includes conceptual change in case of a misconception and understanding concept's boundaries. For concept learning, previous research indicates that people tend to use positive instances and ignore negative instances, even though this is often an inefficient strategy. One measure to push students to look at negative instances is to require an explicit work on erroneous examples.
3. Improve reasoning capabilities, e.g., the correct application of rules and the application of correct rules as well as hierarchical/structured problem solving.
4. Train meta-reasoning, including critical thinking, self-monitoring, and enforce self-explanation to judge solution steps as correct or faulty. Meta-cognitive skills are required to overcome the barriers imposed by the student's prior knowledge and conceptions, and finding and correcting errors in an example can stimulate and prompt meta-cognitive activities. Critical thinking is sometimes neglected for mathematics and its applications. However, in real life people have to be able to judge whether a mathematical result is acceptable or to discover the conditions under which it is correct. In other words, they have to be able to find out the reason for an error. Learning should also therefore, target this capability.
5. Encourage exploration. Borasi (1994) reports striking experiences on how even below-average students start questioning and exploring mathematics, when confronted with an error and encouraged to dwell on it.
6. Change attitudes. In the traditional classroom culture, there is not much room for being wrong, not even temporarily. Schoenfeld (1989) reports that most students believe that if you can't solve a problem in a few minutes, you can't solve it at all. A mistake is interpreted as an ultimate failure and there is little room for experimentation (and debugging). When guessing, experimenting and playing with partially correct conjectures are discouraged, the only remaining alternative for many students is getting 'stuck'. Schoenfeld (ibid.) concludes that this attitude is an important factor in students' inability to cope with non-routine problems.

3. Real-world erroneous examples and vicarious learning

As mentioned earlier, the advantage that real-world erroneous examples may have over a collection of "commonly made mistakes" is that it can provide the context for the errors as well as what process was actually involved in correcting the misconceptions. This is crucially important as only showing the errors and a corrected version may not address the misconceptions that the students may have – only the symptoms of the misconceptions are dealt with. By walking the students through the context of the error and the correction process, the students can in effect learn 'vicariously' from the experience of other students.

Vicarious learning is learning that takes place while observing learning dialogues between a student and a lecturer/tutor (Stenning et al., 1999). The most common instances of this type of learning occurring are during lectures and group tutorials. When a student and lecturer have a discussion in front of the class, the rest of the class learns something from that discussion by observing the dialogue that goes on. The concept of vicarious learning is not new. Chronicles of dialogues (as opposed to continuous prose) have been used for conveying ideas or concepts in a wide range of disciplines for centuries – for example, religion (Poole, 1685), law (Hobbes, 1971) and neurolinguistic programming (Bandler, 1985). On a larger scale, television broadcasts have allowed the public to observe debates and discussions on topics ranging from current affairs to personal issues.

3.1 Vicarious learning as courseware

So where is vicarious learning relative to other courseware (online learning material) that currently exist? As a broad classification, online learning materials can be categorised into three categories of courseware (Mayes, 1995); primary, secondary and tertiary.

The most common of these is *primary courseware*, which is used for introducing concepts to students. This can be in the form of electronic books, online lectures or electronic sources of encyclopaedic form. *Secondary courseware* allows the student to explore concepts learnt from primary courseware in further depth and complexity through performing related tasks. Examples of secondary courseware include simulation programs and modelling tools. *Tertiary courseware* uses as a learning resource the dialogues that take place within the context of the use of secondary courseware or offline learning material. These

dialogues can be in the form of a one-to-one dialogue between a student and a tutor or a classroom discussion on a certain topic. Consequently, the main aim of tertiary courseware is not to present new ideas, but to clarify and facilitate exploration of concepts and assist students when they have misconceptions on a topic. Examples of such tertiary courseware include dialogues captured in the form of Frequently Answered Questions (FAQs) and online discussions in computer-mediated communication (CMC) environments. With respect to this classification, materials that can effectively support vicarious learning can be classified as tertiary courseware.

It is apparent from the classification given above that, while tertiary courseware does not have to be based solely on dialogues surrounding erroneous examples, such dialogues will be rich in content that other students observing the dialogue would find useful for correcting similar misconceptions that they may have. Therefore, in order to implement effective tertiary courseware, it is crucial to be able to capture the learning dialogues that take place during discussions of erroneous examples.

4. Existing systems for capturing learning dialogues

There are many VLEs (Virtual Learning Environment) that allow recorded classroom and tutorial activities to be accessed online. However, few are suited to supporting effective vicarious learning through erroneous examples.

The *Dissemination* tutoring system (http://www.hcrc.ed.ac.uk/Vicar/TT/), as used at Heriot-Watt University and University of Edinburgh, is a simple video-based vicarious learning system consisting of video recordings of the interactions in one window, which is accompanied by notes on the topic under discussions and perhaps the page of the lecture note on the topic in another window. This system makes use of one static camera angle in each video clip and provides minimal support for navigating within the video clip and the props (lecture note) that are provided. The system is used for teaching Human Computer Interaction courses.

On the other end of the spectrum, the *eClass* Project (formerly Classroom2000) at Georgia Institute of Technology (http://www.cc.gatech.edu/fce/eclass/index.html) shows what state-of-the-art lecture recording and dissemination technology consists of. The *eClass* system is the result of a study initiated in 1995 into automated capture of teaching and learning experience via an ubiquitous computing environment (Abowd, 1999). By combining video/audio recording with time-stamped slides and annotation, the system has managed to develop and utilise technologies to effectively put lectures online. To date, 24 'instructors' have used eClass in more than 100 classes. However, this emphasis of putting lectures (i.e. what the lecturer is doing) online means that *eClass* does not focus on student actions (or interaction) and feedback, which is essential for facilitating vicarious learning. The materials that have been captured consist of recordings of lecturers giving a lecture and interacting with an electronic whiteboard with very little or no dialogue with the students in the lecture. Additionally, *eClass* requires expensive equipment such as electronic whiteboards and backup equipment all of which contribute to a significant price tag, making it not cost-effective to implement in an individual lecturer's office or small tutorial rooms, where dialogues between tutor and students (or between only students) around errors made by students would often take place.

Of the two systems presented, neither seems to have the right balance between having the adequate technology to support production of effective vicarious learning material and using the technology already implemented in an appropriate way to support vicarious learning. For example, many video clips in the *Dissemination* tutoring system showed a tutor and a student interacting around some props (either a whiteboard or a piece of paper on the table). Despite both participants frequently referring to these props, the system did not effectively capture what was being pointed to or written on these props. On the other hand, *eClass* use a sufficient number of camera angles to capture lectures for online presentations. However, the overall setup of both systems does not support effective capture of dialogues between the lecturer and the students during lectures or tutorials.

5. Study setup

From previous research into the use of erroneous examples and lecture capturing systems, it is clear that the following questions need to be answered in order to create effective vicarious learning material based on real-world erroneous examples:

1. How, when and where to capture learning dialogues based on real-world erroneous examples?
2. How to create effective courseware from those dialogues?
3. How will the students use the courseware?

4. Will the students, who usually prefer learning with 'perfect answers', accept courseware that contains real-world erroneous example?

A three-phase study was setup to investigate the above issues concerning the use of real-world erroneous examples in VLEs for teaching systems diagram construction (in Computer Science):

- Phase 1: Capturing of real-world erroneous examples and using them in learning material
- Phase 2: Use of learning material real-world erroneous examples
- Phase 3: Students' attitude to learning using erroneous examples

The studies were conducted with student volunteers on first-year undergraduates (freshman) Information Systems course at University College London (UCL). The implications for VLE design deriving from results of the first two phases of the study have already been reported in two previous publications (Monthienvichienchai & Sasse 2002; 2003). In this paper, the results of the final phase (phase 3) of the study are reported. The main intention is to complement the quantitative data that was collected during the first two phases with the rich qualitative data of this phase. This should allow VLE and content designers to create effective learning material containing erroneous examples.

5.1 Capturing real-world erroneous examples

This phase uses contents created during the first two phases of the study as the test material to probe the attitude of students towards using real-world erroneous examples. One particularly suitable tutorial session that was captured was chosen for the study, as it contained many key issues in systems design in one session. The result is a QuickTime ™ video clip containing the conceptual knowledge level of interaction of a tutorial, during which the following topics were covered:

- Data Flow Diagram (DFDs) decomposition
- Physical vs. Logical DFDs
- Linking different levels of DFDs
- Dealing with error conditions in DFDs
- Deriving a pseudocode for a process
- Dealing with missing functionality in the design
- Differentiating system state and system process

These topics are explicitly shown in the video clip by the implementation of QuickTime ™ *chapters*. Additionally, the video clip also implements the following form of navigation features: play, pause, rewind, forward, move to beginning of clip and move to end of clip through 'button' interface; and rewind and forward through a direct-manipulation interface. The video clip is also synchronised with changes that were made to the student's work during the tutorial. This allows the courseware to show what changes are made to the work as soon as it happens in the video clip. The screenshots (Figure 1) below show a close up of the video interface and how the video windows was placed and synchronised with a view of the student's work. The courseware is accessible through a web browser and only requires QuickTime ™ to be installed.

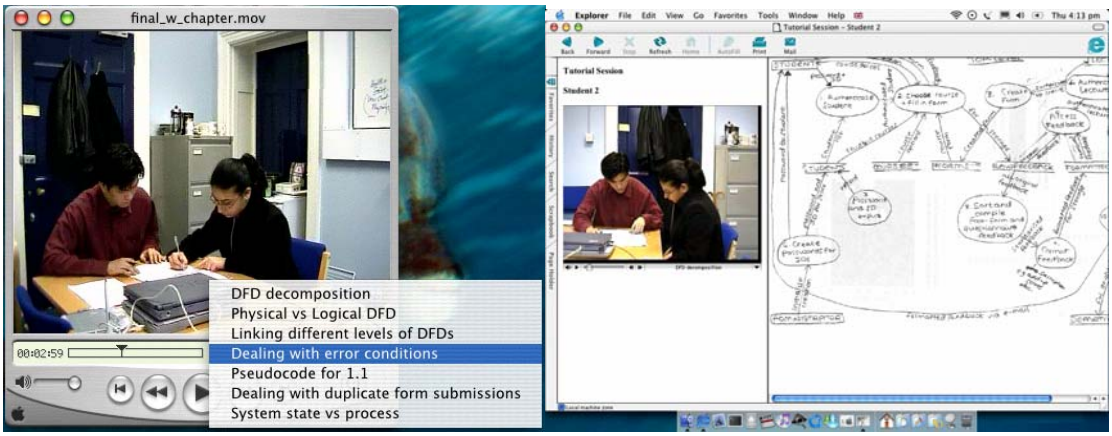

Figure 1: Screenshots showing the video window and how it is synchronised with the view of the student's work

5.2 Subjects

12 students volunteered to take part in the study and were given access to the material developed above. They were given the task of doing a questionnaire-based assignment (see Figure 2 for an excerpt) that corresponds to the concepts that were covered in the material. Each student had unlimited amount of time to complete the assignment under observation. Once the assignment has been completed, each student

was interviewed about their experience of using erroneous examples during the session. They were also informed that the interviewer was not involved with the process of creating the material and their comments will be anonymised.

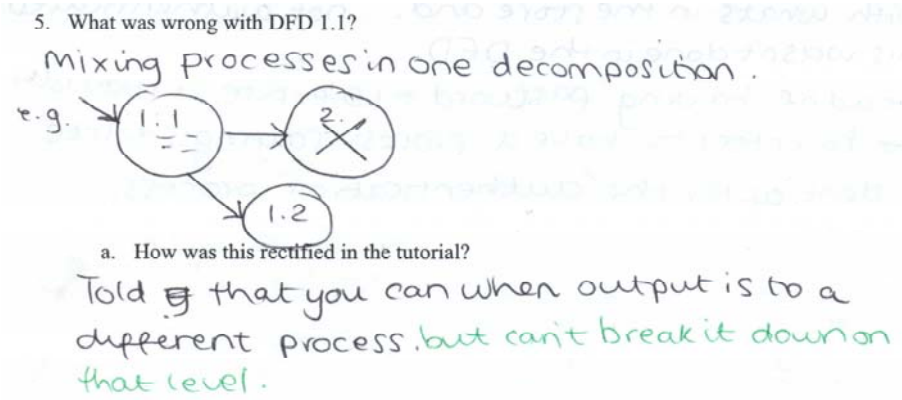

Figure 2: Scanned image of the student's work while interacting with the courseware (1 question out of 7)

6. Students' perceptions of erroneous examples and vicarious learning

Every student who was asked what they thought about being able to see another student's tutorial commented that the ability to see another student's tutorial is very useful. The following sub-sections discuss different categories of students' comments in detail (for accuracy, the transcripts of the students' comments are presented "word for word", i.e. with no grammatical correction).

6.1 Learning from erroneous examples

A common perception among students was that the material allowed them to learn from other student's mistakes and this was perceived to be useful for the students.

> *"I think the ideal [version] will be good as well, but with this, I think you learn from the mistakes, what not to do. The good thing about this is it tells you what not to do and then tells us how to do it. Whereas if you just tell us how to do it, then we'll just copy that and not learning issues in other things."* Student 10

> *"Because you can look at what mistakes they've made and maybe it's something that I didn't really think about. So, it's another chance for me to learn about other people's mistakes so that I don't really make the same mistakes again."* Student 9

> *"Say if you have this common problem with that <student> you may not actually realise it or something but then realise just then that oh I've actually done the same thing as her or him."* Student 11

6.2 Perceived relevance of erroneous examples

Some students commented, more specifically, that the particular material they interacted with would have been very useful for them had they had access to it before they had submitted their most recent System Design coursework (for ethical reason, students who volunteered for this study was given access to the material only after submitting their related coursework). This is despite the fact that the material only raised a limited number of relevant issues for the coursework.

> *"… it's not so much about seeing another person's tutorial, it's being able to see the mistakes that other people make from their work … and how it gets corrected and what the corrections are… Cause, having handed in my coursework, I know I've made some of those mistakes …"* Student 7

> *"Yeah, I think I would have [used it if it was made available during the coursework week] because it would have helped us with like our DFDs and stuff... Because you know we have to do the coursework. Yeah, it might have come in handy for that to see where they make their mistakes so that we don't make the same ones."* Student 8

> *"Because like when I was just looking at that now, because I'm doing a coursework with DFDs I think that is like that's helped me see what could might be wrong with mine, you know, because I have never done DFDs before so it's like. I know it now that you have to think of everything from, not like I didn't know this before the tutorial, but it's sort of given me an example to see how like you can't have sort of "input details" you have to have … you don't even*

need that because it's not a system process, so you know, things like that. So I think even though I'm not doing exactly the same thing as that, it's still helpful to see the sort of comments that you can make on her project. You know you can sort of apply them to your own, which is quite helpful I think." Student 5

6.3 Benefits of real-world erroneous examples

Some students also commented on the social value of the material. More specifically, they commented on how the material helped to boost their confidence by allowing them to see what goes on in another student's tutorial.

"It gives you ideas of what like how you want to prepare yourself when going into a tutorial session because in the beginning she was flipping around and didn't know where to start. So it makes you realize you should be prepared for it and know what you're talking about … because you're going into these assignments not knowing, or expecting, like how much effort and how your work is going to turn out. So, it'll boost your confidence and kind of help you out while going through the process I would say." Student 6

"I think it's helpful in a way because then you can just sort of see the sort of things that will be said in a tutorial. But in a sense it might not be very nice for the student if they don't want their tutorial shown to everyone else." Student 5

This observation is consistent with those made previously by Lee et al. (1999) that one of the benefits of vicarious learning is social which results from "*exposure to peer discussion [that] creates positive feelings of being part of a learning community*". Also, these comments indicate how interaction with vicarious learning material developed for this study can be considered as Legitimate Peripheral Participation (Wenger 1998) in the community of practice of students. In this case, the material can affect the self-identity and the practice of the student interacting with it

6.4 Willingness to share own errors with other students

The student above (Student 5) raised an issue that is not uncommon among students in this study. While every student thought that the material was useful, not all of them were enthusiastic about having their own tutorial sessions recorded. Ironically, the feature of the material that the students find most useful – the ability to see and learn from another student's mistakes – was the main area of concern when considering whether they would allow their tutorial session to be shown to other students.

"It would probably be quite embarrassing because I'll say dumb things and people would laugh or whatever. But I mean, for example, say if it was … I don't know. It'll probably be a bit embarrassing but I mean if it was like come in and look at that where you just don't know who it is then I think it'll probably be fine. Well, you don't actually have to see the girl's face in this and it would still be the same thing... It probably would but I mean to you it would but to them they would just see, o they make like … Say if you make a really silly mistake like if you completely miss you miss a process out, an obvious process out, I mean sure you correct it at the end, but it's just silly for missing the obvious process out in the first place. Which would be…I don't know." Student 11

Another concern when considering whether to share their own errors or not is the fear of plagiarism. Students were concerned that people viewing the material would have an unfair advantage over the person being filmed. However, this was only the case if the student being filmed had the same assignment as those viewing the material.

"I mean if they're doing, if the coursework topic's different to the topic that I'm doing, I wouldn't mind [being recorded] at all because I mean if they can learn something out of the tutorial that we have that will be quite good, because I would like to like see their tutorials as well. But if they're doing the same topic and if they had the chance to look at my tutorial, I don't think I would … no... But I mean if it's a different topic, a different coursework title I wouldn't mind at all." Student 9

One student (Student 8) did not want to be recorded at all, citing a combination of not wanting other people to see her mistakes and the general dislike of being recorded on film. However, the same student said that she would consent if the material can be anonymised so that people would not be able to recognise her.

7. Further analysis

7.1 Causes vs. symptoms of misconceptions

While studying the capture and production of vicarious learning materials (phase 1 of this study), whether as an experiment or a case study, there was one process that consistently took

place when materials were created, which may not have taken place if the tutorial sessions were not being captured to create vicarious learning materials. This process was the tutor's discovery of the cause of the misconceptions in the students' misunderstandings. It is important to highlight the fact that this process actually took place, as it was a fundamental process in creating effective real-world erroneous example based material during this research. When conducting tutorials for students on this course (Information Systems), in order for students to effectively learn vicariously to avoid the mistake made by the student in the material, they needed not only to be able to see the other student's actions (corrections and amendments), but also to understand why those misconceptions happened in the first place. Probing deeper into and identifying the source of the student's misunderstanding, when conducting tutorials for creating vicarious learning material achieved this. Many students on this course (more than a quarter), through their misconceptions, arrived at conclusions (in this case, DFDs) that they knew to be wrong, or at least not totally correct. However, since they did not know how else they could externalise their design, they did not revise their flawed conclusions. However, when students were shown how such misconceptions came about in the first place, they were able to identify misconceptions in their own designs, enabling them to amend their conclusions accordingly.

For this reason, while creating courseware for this case study, it was necessary for the tutor to probe deeper than usual into why the student made the mistakes that he/she did. If the misconceptions are not explained from the student's point of view, the resulting courseware is just an extension of primary courseware, i.e. the material will contain "how not to do it" and will then be followed by "how to do it".

7.2 Erroneous examples and phenomenography

The concept of exploring a student's misconception may not only serve the purpose of creating tertiary courseware. The processes of exploring and categorising how students experience learning are fundamental to the phenomenographic research methodology (Marton, 1981), whose focus is on the variations in ways students experience a certain phenomenon in a certain context. It is possible for the tutor, after conducting individual tutorials with a number of students from the course, to recognise a pattern in the different ways in which students have understood or misunderstood key concepts. Additionally, as a phenomenographic study categorises events in terms of the students' variations on how they experience a phenomenon (Marton and Booth, 1997), it may be feasible to suggest that such categories can also be used to categorise real-world erroneous examples based courseware (as opposed to categorising them using the curriculum structure which may or may not reflect how the students have experienced the course). As a result of exploring the misconceptions of various students on the same topic during the course of this study, it was possible to discover many reasons for students' misconceptions and erroneous actions in their coursework – often the reason behind the misconceptions, while logical, was completely unpredictable.

8. Conclusions

This study has demonstrated the significant potential of courseware that are derived directly from real-world learning experience of students who were dealing with and benefiting from real-world erroneous examples. It highlights the gap that currently exists in the supporting the individual learning needs of students by the current crop of personalised eLearning solutions (e.g. adaptive hypermedia). Such solutions place emphasis on tailoring a vast array of external content to suits certain needs to individual students. However, there is great potential in meeting the individual needs of the students by deriving fewer but better targeted 'home-made' courseware from students' particular cohort, such that he/she can learn from the experience of his/her peers (note that a cohort can also mean a community of students, so the potential for reuse outside a single institution or geographic location is still preserved). VLEs that provide support for collaborative learning go some way in support this need. However, there are many learning dialogues that students would benefit from having access to that are not captured by such VLEs. Professional content developers can also increase the effectiveness of their material by building their content not just on expert domain ontology of the subject, but also on phenomenographic data of how students approach learning that subject. Only by supporting the use and creation of the full spectrum of courseware could a VLE be able to truly support all the learning needs of the student.

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References

Abowd, G.D. (1999) “Classroom 2000: An Experiment with the Instrumentation of a Living Educational Environment.” *IBM Systems Journal, Special issue on Pervasive Computer* 38(4): 508-530

Bandler, R. (1985). *Using Your Brain For a Change*. Utah, Real People Press.

Borasi, R. (1994) “Capitalizing on Errors as “Springboards for Inquiry”: A Teaching Experiment.” *Journal of Research in Mathematics Education*. 25(2):166-208.

Hobbes, T. (1971). *A dialogue between a philosopher and a student of the common laws of England*. Chicago, University of Chicago Press.

Lee, J., F. Dineen, J. McKendree and T. Mayes (1999). “Vicarious Learning: cognitive and linguistic effects of observing peer dialogues”. *American Educational Research Association (AERA '99) Annual Meeting*.

Mayes, J. T. (1995). “Learning technologies and Groundhog Day”. *Hypermedia at Work: Practice and Theory in Higher Education*. W. Strang, V. B. Simpson and D. Slater. Canterbury, University of Kent Press.

Marton, F. (1981) “Phenomenography: describing conceptions of the world around us” *Instructional Science* 10: 177-200

Marton, F. & Booth, S. (1997) *Learning and awareness*. Mahway, N.J., Laurence Erlbaum.

Miller, P.H. (1983) *Theories of Developmental Psychology*. Freeman, San Francisco.

Monthienvichienchai, R. & Sasse, M.A. (2003) “Learning from Others' Mistakes Through Computer Supported Vicarious Learning”. *Proceedings of the 4th LTSN Conference* in Galway, Ireland, August 2003.

Monthienvichienchai R. & Sasse, M.A. (2002) “Computer Support for Vicarious Learning” *Proceedings of E-Learn 2002-World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*, Montreal, Oct. 15-19, pp. 698-705.

Poole, M. (1685). *A Dialogue between a popish priest and an English protestant: wherein the principal points and arguments of both religions are truly proposed, and fully examined*. London, Tho. Cockeril.

Schoenfeld, A. H.: 1989, “Explorations of Students’ Mathematical Beliefs and Behaviour”, *Journal for Research in Mathematics Education*, 20 (4), 338–355.

Stenning, K., J. McKendree, J. Lee, R. Cox, F. Dineen and T. Mayes (1999). “Vicarious Learning from Educational Dialogue”. *Computer-Supported Cooperative Learning (CSCL '99)*, Palo Alto, California, Lawrence Erlbaum Associates, Mahwah, NJ.

Strecker, C. (1999) “Aus Fehlern lernen und verwandte Themen”, [online], http://www.blk.mat.uni-bayreuth.de/material/db/33/fehler.pdf

Wenger, E. (1998) *Communities of Practice: Learning, Meaning, and Identity.* Cambridge, Cambridge University Press.

