Engaging First Year Chemical Engineering Students With Video-Based Course Material

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ABSTRACT

This paper describes a project in which lectures and other supplementary material were captured on video and presented in a CD-based package suitable for students studying first year chemical engineering. Video clips, animated PowerPoint™ presentations and text-based material were combined using Microsoft Producer™, with the various components accessible through a web-style interface, and the package delivered to student on CD's.

The package was evaluated using the "Three I's" framework of Young and Asensio (2002): Image, Interactivity and Integration. Interactivity was key to the pedagogical effectiveness of the package and the enthusiastic response from the students. The package, by combining text, video, slides and quizzes, successfully integrated several elements of communication; future work will also aim to integrate taught material across subject boundaries. The issue of Engagement – ensuring that the students actually engage with the material in a way that delivers a meaningful educational experience – was also identified as a key requirement (Kearsley and Shneiderman, 1999; Hodgson and Asensio, 2001).

In the first part of the project, selected 50 minute classroom lectures on Heat Transfer were captured on video and made available to students subsequent to the lecture, not as a replacement to the live lecture, but intended as supplementary to the lecture as a basis for revision. This initiative was envisaged to have three benefits: (i) the style of lecturing adopted for the initial creation of the video gave variety, which maintained interest; (ii) the mode of learning was altered, both in the lecture and subsequently under the student's own initiative and control, giving greater opportunity to capture and engage students who perhaps did not respond so well to traditional classroom lecturing; and (iii) the opportunity to revisit spoken explanations of subtle concepts was valuable during revision. A slight downside during the initial creation of the videos was that students were unable to ask questions during the lecture, as they would normally do.

As a contrasting approach, in the second part of the project shorter video clips related to 1st Year Chemical Reaction Engineering were created. These clips were typically 10 minutes in length and prepared "off-line" (*i.e.* not in the live classroom environment). These were intended to provide review of key course components and to aid the students to recognise the advantage of course revision. The different "off-line" style was adopted to give variety and again help engage the student. Tutorial questions were provided that appeared automatically following the end of each clip.

The project was evaluated through student feedback questionnaires, which showed overwhelming enthusiasm for the initiative. Particularly attractive was the control given to the students to receive lecture material at their own pace and under their own control, and the variety and interest the material added to the course. Practical issues included guarding against any temptation on the part of students to miss the live lectures and, related to this, the most appropriate timing for dissemination of the CD's, as well as the practicalities of creating the video material and the delivery package. Video clips of laboratory practicals was identified as potentially beneficial and appealing, and future work will aim to add these to the suite of material available.

This project was funded through an ExxonMobil Higher Education Support Scheme award and facilitated through the Click and Go Video project (http://www.clickandgovideo.ac.uk).

Keywords

video, chemical engineering, heat transfer, chemical reaction engineering, engagement, interactivity, integration

INTRODUCTION

Traditional classroom lecturing is an effective and efficient means of educating engineers, as part of a broader suite of delivery mechanisms. The face-to-face element of lecturing underpins its effectiveness as a mechanism for communicating understanding of concepts in a way that alternatives do not. However, lectures suffer from a temporality that compromises their effectiveness – the student and lecturer must be engaged at the same time, and the interaction is one-off and generally cannot be revisited. This paper describes a project in which lectures and other supplementary material were captured on video and presented in a CD-based package for students studying first year chemical engineering.

In the quest for ever more effective teaching strategies, moving images have consistently emerged as potentially powerful tools for use within education. At the same time, the paradigms of education have shifted away from teacher-directed instruction towards more learner-centred study. Modern technological developments in terms of the rise of the world wide web and the ready availability of digital video recording and editing facilities are helping to bring these two themes together, such that the use of digital video can enable richer and more effective student-centred educational experiences.

Young and Asensio (2002) and Thornhill *et al.* (2002) review the development, use and benefits of video in education, and describe the Click and Go Video project that aimed to address the alignment of streaming video technology, pedagogy and infrastructure (http://www.clickandgovideo.ac.uk). They note that video technology is a focus for educational innovation, not a driver, summarised by the exhortation that "Pedagogy comes first!" – video technology must not substitute for or distract from the pedagogical obligation to design meaningful learning events. However, having recognised that obligation, video then becomes a powerful tool for delivering pedagogical objectives. Video-based material can also contribute to the tilt in the balance from teacher-centred instruction to learner-centred study, and offers an alternative support mechanism for different learning styles.

Young and Asensio (2002) introduce a framework for designing and evaluating video-based teaching material, which they call the "Three 'I's framework". Based on reviewing the literature and compiling comments from participants in video workshops, they see three overlapping elements of video as it relates to educational effectiveness, summarised as: Image, Interactivity and Integration.

The value of "Image" is "to complement and add visual richness to learning resources". For some video-based learning materials, the quality of the image is crucial to the information to be conveyed, and image quality is the highest priority in developing the material. The use of professional camera technicians and careful lighting would therefore be required, and the video would need to be delivered over high bandwidth lines to maintain image quality. For other purposes, the quality of the image is secondary, a home video camera would suffice for capturing the video, and poorer quality images delivered over the internet would not compromise the learning.

"Interactivity" is the second key to delivering effective video-based teaching material, taking on a greater priority for some applications than for others. Young and Asensio quote Rosenberg (2001) who notes that "…the main reason why television did not become everyone's teacher was because it lacked the very essential quality of teaching: the ability to interact with the learner…". Computer-based digital video opens up great opportunities for interactivity to be built into the package. Interactivity relates primarily to: Access (availability of material asynchronously and independent of location), Choice (a library of materials available on demand) and Control (the ability to start, pause and replay material) (Young and Asensio, 2002). The Three 'I's framework encourages educators to consider to what extent Interactivity is essential to the pedagogical objectives of the learning experience they are designing.

The third element of the framework is "Integration". Video can be used on its own, but more frequently it is combined with slides, supporting text, links, quizzes, *etc.* as part of a "virtual learning environment" that enhances the quality of the communication. The elements of "Image", "Interactivity" and "Integration" also reflect the shift in the educational paradigm towards more student-centred learning – interactivity gives the learner access, choice and control, while integration caters for different learning styles and preferences.

The objectives of the work presented in this paper were to demonstrate the facility to make videos of course material available to chemical engineering students, to evaluate the students' attitude towards and use of such a facility, to obtain feedback on elements related to the presentation formats in which material was delivered, and to assess the educational effectiveness and benefits of this approach, as a basis for deciding whether and how future material like this should be developed and presented.

METHODS

Two lectures from the Heat Transfer course delivered by Dr Campbell to 1st year chemical engineering students at UMIST were captured on video during the 2001-2002 academic session and digitised. The lectures cover the derivation and solution of conduction heat transfer equations, and were selected for this project because they are considered the most important lectures of the course and those most conceptually difficult for the students. The lectures were 50 minutes in length, and were delivered with the aid of a PowerPoint™ presentation and an accompanying handout. The handouts for these two lectures contained complete explanatory text, but with blank spaces for diagrams and equations, which the students filled in as they came up on the PowerPoint™ slides. This was designed to maintain participation by the students during the lecture and to reinforce the significance of the equations through having to copy each term down.

As a contrast to the videos of live lectures, a conscious effort was made to "chunk" key elements of Dr Garforth's 1st year course Introduction to Chemical Reaction Engineering, to contrast the live 50 minute lecture style in order to determine if a preference existed for communication style. In addition, these elements were recorded outside of the lecture theatre (termed "off-line") to avoid background noise and other distractions.

The two principal elements of the lecture, the video and the PowerPoint™ presentations, were combined into delivery packages using Microsoft Producer™ (http://www.microsoft.com/office/powerpoint/producer/). Slides were carefully integrated such that the animations and builds within slides and the transitions between slides synchronised with the video. Control buttons allowed the video to be played and paused or to jump to previous or subsequent slides, while a live index allowed the user to jump directly to any section of lecture. For the Heat Transfer lectures, a link was provided on the web-style interface to open a window containing the handout that accompanied the live lecture. At the end of each of the Introduction to Chemical Reaction Engineering clips, a link appeared automatically that offered users the opportunity to evaluate their understanding through a series of brief tutorial questions. The final package containing the two Heat Transfer lectures and three Introduction to Chemical Reaction Engineering clips (a total of 125 minutes of video material) was copied onto CD's and accessed through a web-style menu which displayed automatically when the CD was loaded.

An early version of the CD package was distributed to several 2nd year chemical engineering students. Feedback from these students allowed improvements to be incorporated into the final package. The final CD package was distributed to 1st year chemical engineering students from the 2002-2003 academic session, immediately following delivery of the second of the two Heat Transfer lectures in March 2003. A week later these students were due to sit a mid-course test in Heat Transfer, at the end of which they were asked to fill in a feedback questionnaire related to the CD package. In this questionnaire several statements were put to the students, and they were asked to provide a rating from 1 to 5, where 1 = strongly disagree with the statement, and 5 = strongly agree. For some statements an additional question, such as "Why or why not?", was posed, and a space allowed for a comment on each statement, with any further comments invited at the end of the questionnaire. The statements and questions were as follows:

- I found the CD easy to load and operate. Any comments?
- The technical quality of the CD was high. Any comments?
- I would prefer the CD *instead* of the live lecture. Why or why not?
- I would prefer the CD *before* the lecture. (1 = strongly disagree = I would prefer the CD *after* the lecture.) Why?
- (Ignoring the differences between Chemical Reaction Engineering and Heat Transfer and the lecturers involved) I preferred the shorter clips rather than the full 50 minute lectures. Why or why not?
- Videos are useful teaching tools for chemical engineering.
- I find lectures given using the blackboard better than the live lectures using PowerPoint presentations. Why or why not?
- I found the material easier to follow from the CD than from the live lecture. Why or why not?
- I would like all lectures to be videoed and available in this format.
- If videos of lab experiments were available, I would use them. What for? Before or after the lab class?
- When using videoed lectures for revision, I would watch the entire lecture (1 = strongly disagree = I would select certain sections only).
- If more 50 minute lectures were available in this format, I would sit and watch them.
- Any other comments

RESULTS AND DISCUSSION

Figure 1 shows a screenshot of one of the Heat Transfer lectures. The feedback from the 2nd Year students who piloted the early version of the package was overwhelmingly positive: "It's unbelievable… This is the way forward for people who prefer to learn via vision and sound"; "If it were possible to get similar learning aids for our exams this year I'm sure it'd be much appreciated!"; "Yes, I would definitely use it, it would be great especially when revising."; "Very clear and understandable"; "Overall very good, a useful tool". A number of practical suggestions were offered and were used to improve the final version of the package.

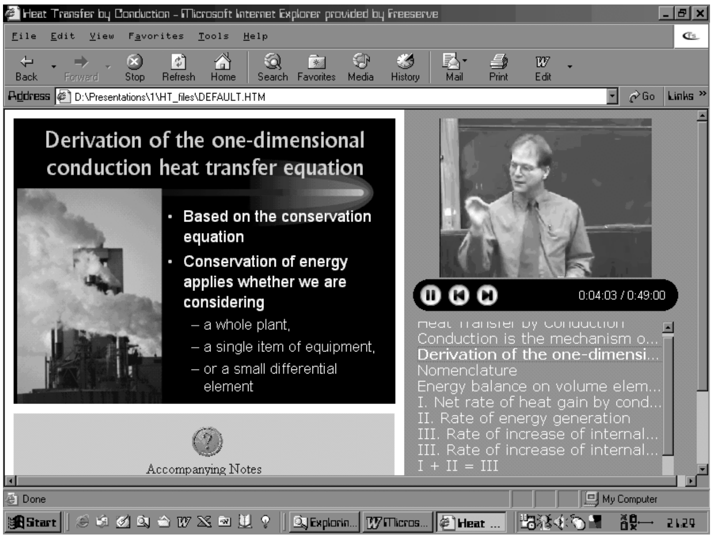

Figure 1. Screenshot from the Heat Transfer lecture "Heat Transfer by Conduction".

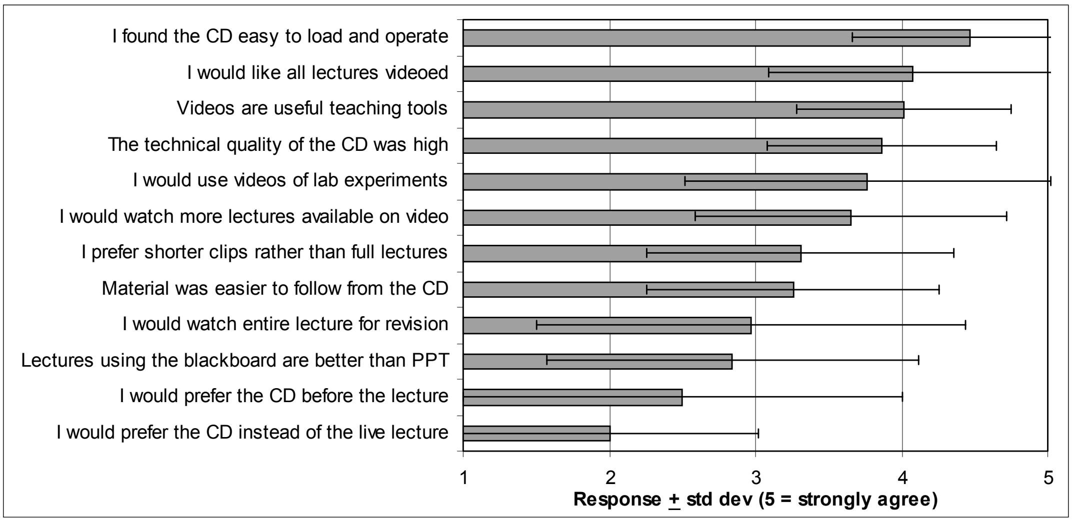

Figure 2. Average response and standard deviation for each statement

Owing to the short timescale between distribution of the CD to 1st year students and the questionnaire evaluation a week later, only 34 responses were received out of a class of 75, the others not having had a good look at the package at that point. Nevertheless some clear themes emerged. Figure 2 shows the average score out of 5 for each statement, ordered from highest to lowest score, and shows also the standard deviation of responses, indicating the degree of consensus among the students in response to a particular statement. Figure 3 shows the profile of 1's, 2's etc. for each statement, similarly indicating the degree of consensus in the responses.

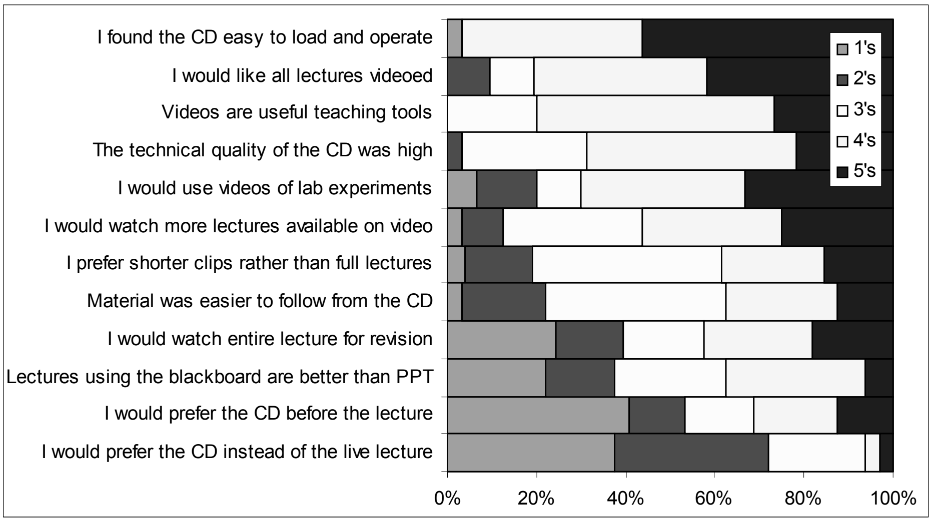

Figure 3. Profile of responses for each statement

The statements also provoked different responses in terms of the extent of comments offered. Figure 4 shows a simple count of the number of students commenting in response to each statement, as a percentage of the total number of questionnaires completed.

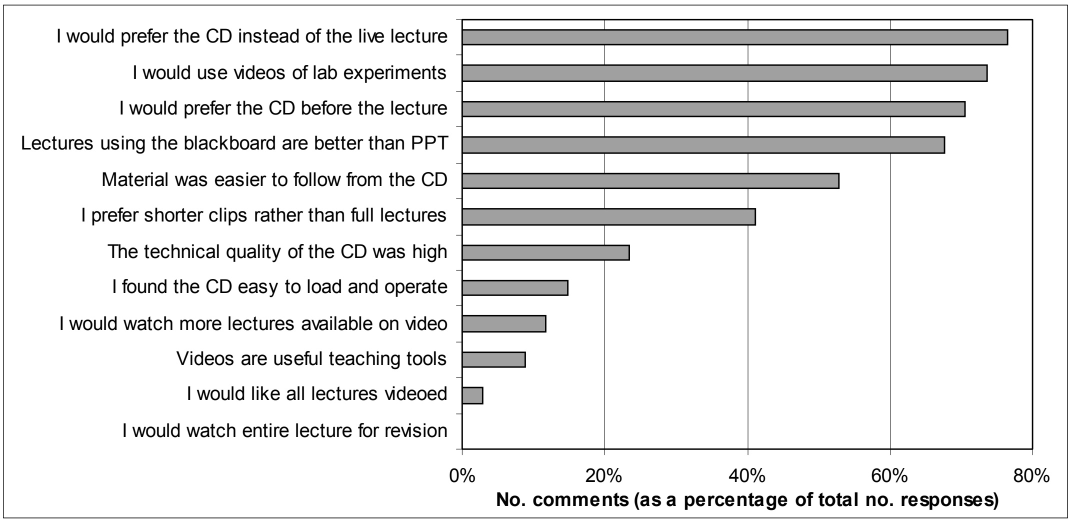

Figure 4. Number of comments elicited in response to each statement, as a percentage of the total number of questionnaires completed.

Figure 2 shows that the top four scores related to two themes: the quality of the CD package, and the perceived usefulness of videoed material in chemical engineering courses. As noted by Zenios (2002), quality and ease of access of this type of teaching material has pedagogical implications; poor quality detracts from the influence and interest of the material, while technical shortcomings create barriers to accessibility and use. It was therefore gratifying that the ease of operation and technical quality of the CD elicited high scores. The high scores in response to the statements regarding the usefulness of video in chemical engineering and whether it should be applied to all lectures give encouragement that students perceive this to be a useful teaching and learning tool. The related statement "If more 50 minute lectures were available in this format, I would sit and watch them" also scored well above a neutral position.

The next highest score related to the statement "If videos of lab experiments were available, I would use them". This statement and its supplementary questions also elicited the second largest number of comments. The vast majority of students indicated that they would use the video before the experiment, so as to understand what they were doing in terms of experimental procedures and safety. A significant number of these students also felt it would be useful for reviewing after the lab. Other perceived benefits included saving time in the laboratory.

"I preferred the shorter clips rather than the full 50 minute lectures" produced the next highest average score, with a moderately high standard deviation, although over a third of students scored this a neutral 3. 41% of students made a comment on this statement, mostly coming from those who agreed with the statement, and mostly indicating that they found it easier to maintain attention with shorter clips, and that it is hard to watch a computer screen for a long time. Those who scored 3 commented that both formats were useful and recognised that the navigation panel enabled pausing or a particular desired section to be selected.

The next highest score was obtained for the statement "I found the material easier to follow from the CD than from the live lecture", although by this stage over 40% responded with a neutral score. Over half of the students made a comment. Those who agreed with the statement cited the ability to pause and to replay unclear points. Against this was the interaction and opportunity to ask questions that the live lecture affords. The statement "When using videoed lectures for revision, I would watch the entire lecture" similarly elicited an almost exactly neutral average response and a wide range of responses, very evenly balanced over the range, and the second largest standard deviation, indicating little consensus. It appears that some students prefer the coherence that a full lecture gives, while others prefer to select only certain sections.

Overall the students gave a very slight thumbs down to the statement "I find lectures given using the blackboard better than live lectures using PowerPoint presentations", but again with a wide range of responses and numerous comments. Those who favoured lectures delivered with the aid of PowerPoint™ presentations felt that the material was more clearly organised and more visually interesting. Those who favoured the blackboard gave reasons such as "when you copy things off the blackboard you take them in more", and also found the pace of lectures in which material is written on the blackboard easier. Again, the range of responses and comments indicates that students appreciate variety, both to maintain interest and because individuals learn differently.

The remaining two statements, "I would prefer the CD before the lecture" and "I would prefer the CD instead of the live lecture" gave resounding rejections, particularly the latter which also provoked the highest number of comments of any of the statements. The overwhelming reason was the opportunity for interaction with the lecturer and to ask questions in the live lecture, with the CD viewed as strictly a revision tool.

In addition to the above, a number of students volunteered further comments, overwhelmingly positive with phrases including "extremely useful and a good idea", "CD a very good idea and very useful for revision. Hopefully we will be seeing more of these.", "Very useful tool, very impressed" and "SUPERB!!! Very helpful, I can repeat it as many times as I like". Despite this praise, "still should carry on with the live lectures". It is clear that engineering students consider live lectures the cornerstone of a university education, but that supplementary tools such as this are highly valued for enabling effective revision and maintaining interest.

Evaluation of the CD package through the "Three 'I's" framework

The "Three 'I's" framework of Young and Asensio (2002) suggests developing and evaluating video-based teaching material with respect to Image, Interactivity and Integration, to identify the element(s) that contribute most critically to the pedagogical objective(s). In this work the pedagogical objectives were: (i) to enhance the effectiveness of revision; (ii) to respond to the different learning styles of individual students; and (iii) to enhance the interest of the chemical engineering course by providing variety.

"Image" does not immediately leap out as the key factor for this work. The images of the two lecturers were not critical to the knowledge and understanding being conveyed, compared with, for example, the videos demonstrating cooking of salmon described by Zenios (2002). More important perhaps was the sound quality; the lecturers needed to be clearly heard and understood. If the work were extended to include demonstrations of laboratory procedures and experiments, then image quality as well as content would become more significant.

"Interactivity" was clearly a key factor both in the objectives of the lecturers in developing the package, and in the enthusiastic response of the students using it. This element moves the centre of teaching and learning from the lecturer towards the student, and is responsive to the different needs and learning styles of students.

"Integration" is the third strand identified by Young and Asensio that contributes to the pedagogical value of video. They use the term with respect to integrating several elements and communication channels within the package itself, such as video supported by PowerPoint™ slides, text, quizzes, discussion rooms *etc.* In this respect the package developed here successfully combined video, PowerPoint™, text and quizzes to provide complementary channels of communication for the material presented. However, there is an alternative use of the term "integration" that is relevant to the teaching of chemical engineering, and that is integration across subject boundaries. A common complaint of engineering educators is the apparent inability or disinclination of students to make links between material taught within different courses. Students tend to parcel the material taught within a particular module and treat it as entirely distinct from material from other modules. There is an opportunity to encourage integration of subject material within video-based packages such as the one described. Such activities would add value beyond the use of the package as merely a revision and reinforcement tool.

Beyond these three elements of Image, Interactivity and Integration is the issue of Engagement – ensuring that the students actually engage with the material in a way that delivers a meaningful educational experience. Thornhill *et al.* (2002) note "Educational video is not a type of incidental learning, the learning still needs to be organised as part of an externally guided, deliberate learning experience". Engineering educators must use such tools within the context of a carefully considered and designed educational experience to ensure that students wrestle with and master core competencies to an appropriate degree. Students clearly view the lecturer presenting material in the classroom environment as the first plank towards building understanding; however, beyond this, and often not perceived by students, is the broader management of the learning experience.

The proof of the package is in the exam results. It was not possible in this study to evaluate the effectiveness of the CD formally and quantitatively by comparing the examination performance of a group using the package against a control group denied the package. However, the authors were disappointed that, despite their efforts to produce the package and the students' enthusiastic reception of it, the performance in the end-of-year exams on questions specifically related to the material on the CD was mediocre.

As noted above, provision of such material incidentally and with the optimistic expectation that it might prove useful overlooks the obligation to manage the educational experience. The first plank of such management is Engagement of the student. Kearsley and Shneiderman (1999) introduced Engagement Theory as a conceptual framework for technology-based learning and teaching. They state "The fundamental idea underlying engagement theory is that students must be meaningfully engaged in learning activities through interaction with others and worthwhile tasks… we believe that technology can facilitate engagement in ways that are difficult to achieve otherwise." and go on to note "Engagement is different from many older models of computer-based learning in which the emphasis was on individualised instruction and interactivity. Engagement theory does promote interaction, but human interaction in the context of group activities, not individual interaction with an instructional program." They summarise the three aspects of engagement as Relate-Create-Donate, by which they imply that effective learning activities: (i) occur in a group context (i.e. collaborative teams); (ii) are project-based; and (iii) have an authentic external focus. Their ideas are relevant to the current project in warning against any temptation to provide video-based material without the context of a well-designed and engaging activity in which human interaction is still prominent.

Hodgson and Asensio (2001), in the context of an evaluation of video-conferencing in learning, considered that engagement is potentially of greater influence on the students' experience than the communication medium. They argued that perceived problems with video-conferencing, such that it is frequently viewed as a "second-best" learning experience, have more to do with the way the learning event has been designed and managed than with the shortcomings of the medium itself. They also considered that, against the "active" emphasis of Kearsley and Shneiderman, that student engagement can be passive and vicarious, through the lecturer's use of story telling, use of metaphor and visualisation to connect the learning to the wider world.

From this brief consideration of the elements of engagement of learners, some suggestions for more effective use of video packages such as that considered here emerge. Firstly, the videoed lectures and clips could be designed to be more intrinsically engaging through illustrated examples and stories (the apparent formality of videoed lectures can deter a lecturer from including the more personal illustrations they might naturally include otherwise). Secondly, the video material available incidentally to the students, perhaps through an on-line library that they access voluntarily, can be tied directly to other tasks to which the student is more committed, such as larger collaborative project work of the type promoted by Kearsley and Shneiderman.

Related to engagement is Mastery of the taught material; engagement precedes, but does not guarantee, mastery. An irony of the current project may be that the attempt to engage students by adding variety and interest to delivery media, and to respond to different learning styles and preferences, was actually counterproductive to their learning. Hodgson and Asensio (2001) in their work on video-conferencing observed "The majority of the students… took notes or jotted things down occasionally, however, some of them took no notes at all since they were able to download the lecture notes from the web." They also note "A striking finding… was the number of times students referred to feelings of boredom to describe either their own experiences or those of others." These two observations are probably related, and illustrate the counterproductive effect that can result from an overly generous teaching approach; in this case, removing the incentive to take notes reduced participation and concentration in the lecture and also removed the particularly effective communication and assimilation channel that writing represents. In the current project, the authors are left with a niggling concern that providing ready access to such clear explanations subsequent to the lecture fooled many of the students into believing that had mastered the material, because they could follow the lecture. Learning is an intellectual struggle, and alleviating the struggle may have lessened the learning.

CONCLUSIONS

The video-based CD package that delivered full lectures and shorter video clips, accompanied by PowerPoint™ slides, text and tutorial questions, was enthusiastically endorsed and used by 1st year chemical engineering students. Students found the interactivity and control enabled by the CD package to be key factors in its appeal, while the integration of the different communication elements within the package enhanced understanding. However, students were clear that such a package was only useful as revision material supplementary to traditional live lectures. The issues of managing the educational struggle such that students engage with and master the material were identified as key.

ACKNOWLEDGEMENTS

The authors are grateful to ExxonMobil for a Higher Education Support Scheme award for this project. They also thank Sally Thornhill, Paul White, Clive Young and Mireia Asensio of the Click and Go Video Project.

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