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The "Intelligent Classroom": changing teaching and learning with an evolving technological environment

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Abstract

Putting technology to work to improve teaching and learning is the goal of the "Intelligent Classroom" project at McGill University. A hardware and software installation allows for the automated capture of audio, video, slides, and handwritten annotations during a live lecture, with subsequent access by students. The development process, a collaborative effort of computer engineers, educational specialists, professors and students, is described, as well as usage by students in four different classes following the initial deployment of the system. Students were found to access the systems as a review tool, and appreciated the changes to the in-class presentation as well as the opportunity for later access. Students' and professors' reactions are described, as well as suggestions for future developments. © 2002 Elsevier Science Ltd. All rights reserved.

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In recent years there has been a growing and explicit focus on improving undergraduate teaching in the Faculty of Engineering at McGill University, due to a general trend to emphasize the importance of teaching (http://www.mcgill.ca/Secretariat/Academic/chap1guide.html), and to the fact that the Faculty of Engineering has been identified as having relatively low student satisfaction with the quality of teaching (In-Touch, 1998). McGill, however, is not alone in recognizing the necessity to improve undergraduate education in engineering, as Kyle's (1997) characterisation of the "imperative" to improve engineering education attests. And although there is significant energy going into alternatives to traditional lectures (see for example, Brown, 1995; Carlson & Berry, 1999; DeLoughry, 1995), lecturing continues to be a major, if not the

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major, instructional method in higher education (Pence, 1997). This paper reports on a project that is changing the teaching and learning environment in the Engineering Faculty at McGill University, a research-intensive North American university.

The use of technology in its myriad forms is having a significant impact on the nature of the physical and pedagogical learning environment in which post-secondary students are operating. The movement towards interactive technologies as tools for learning is accompanied by a call for developmental research in this area, i.e. research "focused on the invention and improvement of creative approaches to enhancing human communication, learning, and performance through the use of interactive learning technologies" (Reeves, 1999, p. 18). While much of the discussion surrounding the use of the Web in higher education focuses on innovative practices in distance education, there is a growing trend towards a mixed-mode approach, with telelearning components being integrated into traditional, face-to-face courses (Bracewell, Breuleux, Laferrière, Benoit, & Abdous, 1998). At least in Québec, the short-term vision is that in 2010, most university-level teaching will still be campus-based, and this means that "re-designing" the classroom[1] is an area that warrants significant attention (CREPUQ, 1999). This focus on classroom-based education, with technology supporting an enriched presentation environment and review capabilities rather than playing a primary teaching role, either synchronously or asynchronously, means that the work done on using video in teaching is not applicable. Because of the complexity of the computing environments being developed, most work has focused simply on the creation of workable evaluation prototypes, and has only recently begun to examine the impacts on teaching and learning (Abowd, 1999).

One example of an enriched teaching environment is the "Intelligent Classroom" project (http://www.cim.mcgill.ca/~jer/projects/iroom).[2] This project addresses three main teaching and learning concerns: facilitating professors' use of a variety of presentation modes in class by creating a transparent interface for managing the environment; enabling students to review lecture content and materials critically and to interact asynchronously with their professor; and enabling alternative means of student evaluation (namely presentations) to be implemented. A multi-disciplinary team at McGill, with research and technical backgrounds in engineering (specifically human–computer interaction and artificial intelligence), educational technology, and multimedia design has been working on the development of an enhanced Classroom 2000 environment (Abowd, Atkeson, Brotherton, Enqvist, Gulley, & Lemon, 1998). Similar to the approach taken in the design of a reactive videoconference room (Cooperstock, Fels, Buxton, & Smith, 1997), presentation technology was installed in the McConnell Engineering 13 (MC13) classroom and augmented with sensors and computers for processing and control. The room now activates and configures the appropriate equipment in response to instructor activity without the need for manual control. For example, when an instructor logs on to the classroom computer, the system infers that a computer-based lecture will be given, automatically turns off the lights, lowers

[1] Note that in North American English, the term "classroom" is used at the university level, as well as at primary/secondary; the term "lecture theatre" may be more familiar to British readers.

[2] Financial support has been received from the Dean of Faculty of Engineering, a research grant from the Government of Quebec's *Fonds pour la Formation de Chercheurs et l'Aide á la Recherche* (FCAR), the Natural Sciences and Engineering Research Council of Canada (NSERC), a Young Innovator Award sponsored by Petro-Canada, and a grant from the Royal Bank Teaching and Learning Improvement Fund, Centre for University Teaching and Learning at McGill University.

the screen, turns on the projector, and switches the projector to computer input. The simple act of placing an overhead transparency on the document viewer causes the slide to be displayed and the room lights adjusted to an appropriate level. Similarly, audiovisual sources such as the VCR or laptop computer output are displayed automatically in response to activation cues (e.g. the play button pressed on the VCR; the laptop connected to a video port). Together, these mechanisms assume the role of skilled operator, taking responsibility for the low-level control of the technology. To a large extent, the idea of automating these aspects (in principle) frees the professor to concentrate on the lecture itself, rather than the user interface or the technology. To a large extent, the idea of ''intelligence'' refers not so much to the classroom, but rather the instructor's ability to use the room ''intelligently'' since the technology (in principle) frees the professor to concentrate on the lecture rather than the technology.

In addition to managing the in-class lecture presentation, MC13 provides a mechanism for the capture, collation, and synchronisation of digital notes, written on an electronic whiteboard or digital tablet, with an audio-visual recording of the lecturer. The system then allows students to review lectures, either in randomly accessed portions, or in their entirety, through a conventional web browser, either from networked university computers or home computers connected by modem. Fig. 1 presents a sample of what one sees when reviewing a recorded lecture: the original PowerPoint slide, in-class annotations, an audiovisual recording of the lecture, and a list of slides permitting direct access to any slide in the class.

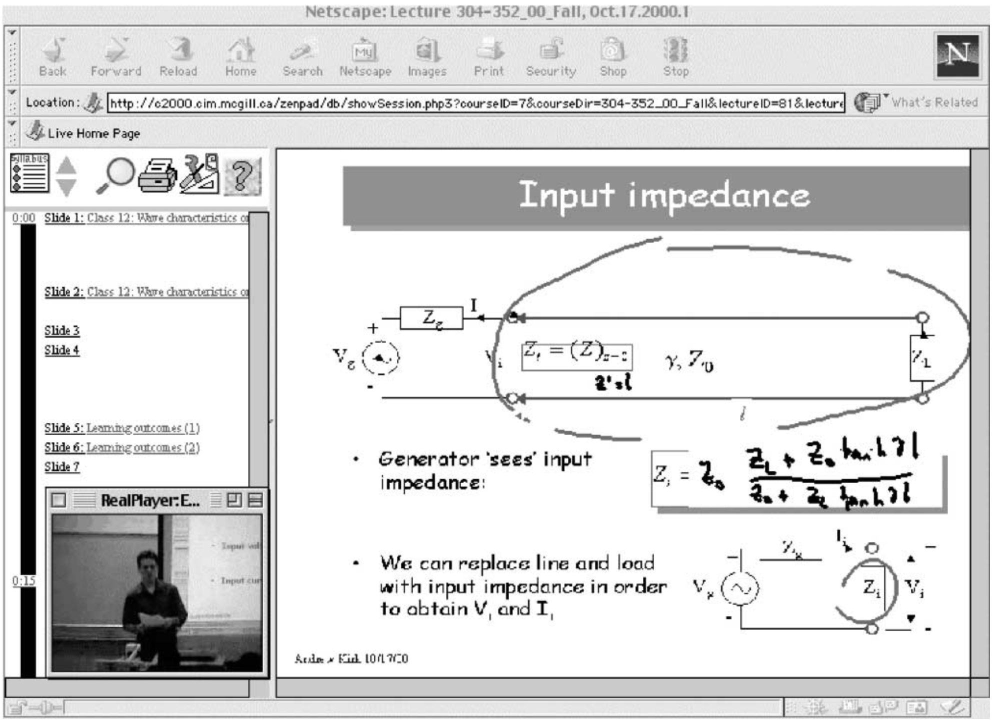

Fig. 1. A sample recorded lecture being viewed through a web browser and RealPlayer.

1. Design and development

In the Fall of 1999, the "Intelligent Classroom" was launched to great fanfare. Briefly, the "Intelligent Classroom" (MC13), is a room in the McConnell Engineering building that is equipped for audio, video and computer recording of whiteboard, VCR, document and handwritten digital ink. Each professor logs into the room, and the system then adjusts to the professor's previously recorded preferences. There are two multimedia projectors available, each of which can display output from a built-in PC, VCR or document camera, or from an external device such as a professor's laptop computer. The default configuration of the projectors is for one to display the current slide, with the second displaying the previous slide. An overflow crowd of students and faculty attended a demonstration of the room's capabilities that included an explanation of the rationale behind its development. This stressed two points: (1) the desire to provide a transparent interface for professors wishing to use multiple presentation media; and (2) the recording of all presentations, including in-class slide annotations, and lectures, and their automatic uploading for later review by students.

Since that date, the system has undergone numerous improvements (and continues to do so), some addressing issues of robustness of existing features while others have provided additional features, and the design process itself has represented an innovative collaboration of educators and software engineers. Many people have been and continue to be involved in the development of the "Intelligent Classroom." The bulk of the actual development work has been done by undergraduate students, with supervision and assistance by the second author. The evaluation work has involved graduate students in education, under the supervision of the first author. Undergraduate students, as well as other professors in the Faculty of Engineering, have participated in the prototype review sessions. Engineering professors using the system as it develops, and their students, have provided feedback on successive iterations. The basic lecture capabilities of the room were an installation of the Classroom 2000 work from Georgia Tech (Abowd, 1999; Abowd et al., 1998), but the current incarnation has extended the opportunities afforded by the technology significantly.

1.1. The pedagogy/engineering interaction

The design and development process merits a brief description, as it represents a truly collaborative effort between software engineers and educators, and professors and students. During the course of the project, there was a constant give-and-take between the technological and pedagogical interests, with each significantly influencing the final product. In other words, just because something was technologically possible did not mean that it was implemented; pedagogical "wish lists" had to respect technological limitations but at the same time encourage innovative design features.

An initial design team of two engineering professors (one from computer engineering and one from metallurgy), one education professor, two undergraduate engineering students, and one graduate education student, met four times to discuss what became the first extensions of the original installation: a student mini-presentation system and a PAQ system (Previously Asked Questions). Establishing a common ground and language for dialogue as well as respect for the different perspectives represented were important stages in the development process. The implications of design decisions on the people involved; i.e. the professors and the students, as well as on the rest of the system; i.e. lab resources, were key issues that were actively addressed by seeking input from support staff and students.

Evaluation issues addressed included both program robustness and functions, and educational effectiveness. These require two different approaches; however, the areas of overlap are obvious: systems that crash or don't have intuitive interfaces are not conducive to fostering effective teaching or learning. Also, the kind of learning supported by such environments is not necessarily the same as with traditional learning environments: attention must be paid to evaluating the impact of the learning environment on the nature of the learning experience itself. One concern that was raised by both faculty and students is that a high quality lecture capture system may encourage students to skip classes; putting the tool in its place, so to speak, will be a central concern in the development of the implementation strategy and evaluation of its real as opposed to intended use.

1.2. What difference does collaboration make?

Engineering professors involved in developing new computer-based systems tend to be technology-driven: *"If it's interesting, let's build it!"* While the impetus for this project grew out of a genuine concern for improving the teaching and learning environment for professors and students, it quickly became clear that sometimes the "solution" envisaged by the engineers was not necessarily the most productive approach to take from a pedagogical perspective. The clearest example of how engineering and education influenced each other is in the evolution of the originally proposed feature, the "Critic," to the PAQ. In a standard engineering model, one solves problems by providing feedback; ergo, what better way to "solve the problem" of poor teaching than by providing professors with feedback on their performance, or a built-in critic. So far, so good. However, the form of the feedback as originally envisaged was limited to the sparse information content of "yes/no" answers to questions concerning technical aspects of the professor's performance. There was no mechanism provided that would allow students to express conceptual difficulties, or for professors to gain any insight into if and how the content of their lectures was being understood by the students. Through discussion with students and education experts, the system moved from being a real-time to an asynchronous assessment of teaching mechanics, as it was quickly recognized that it was unrealistic to expect instructors to adjust themselves "on the fly," and for students to provide continuous feedback while they were supposedly focusing on the content of the lectures. The more significant fruit of the engineering/pedagogical exchange, however, was the bringing out of the importance of students' questions and thoughts as they interacted with the content. The resulting tool—the PAQ—permits some insight into students' concepts and any difficulties they face, and allows students to benefit from others' questions as well. This expands an educational environment that was previously concerned largely with technical aspects of the human–computer interface to one that begins to support a constructivist view of learning as reflected in current thinking on the nature of learning (Mezirow, 1997). The technological challenges, and therefore interest for the engineers, were no less real for the reconceptualised system, but it now would be a system with much greater pedagogical utility and validity than the original idea.

Educators involved in designing new computer-based systems, on the other hand, are often limited by the fear, not to mention the real difficulties, of actually having to create what they design, either themselves or having to find the financial and human resources to do so for them. However, because this fear is often based on an incomplete understanding of technological capabilities, limitations and constraints, it can lead to unrealisable designs, or designs that are unnecessarily limited in their scope due to misplaced fears of technological difficulties. By having the design process from a pedagogical perspective intimately linked to the technical design, ideas could be explored freely, but within a context that assured the design would be within the realm of the possible. The advantage of working with engineering professors and students to realize the project is that the "realm of possibility" is not limited to what is readily available, but can look forward to more innovative developments.

The question of user-interface is a separate area where educators are often frustrated by being asked, if at all, to comment on the interface when it is already in beta version, if not later. Suggestions for change at that point are often regarded with some dismay by the developers, as even apparently minor modifications may require important redesign efforts that could have been avoided if this input had been received earlier. Working within a context of participatory design, that is, the educators working alongside the engineers as designers of the system, helped avoid such pitfalls. For the engineers, having the educators as an integral part of the design team meant that this input was provided on an on-going basis—as decision points were reached, the input was provided.

1.3. New features for the Intelligent Classroom

The major additions have been the Previously Asked Questions or PAQ interface and the Mini-Presentation system. The PAQ (deployment Fall 2000) permits students to peruse student-posed questions pertaining to any slide, or submit new questions of their own while reviewing lectures on line. At a click of the mouse, a list of previously asked questions (with answers) pertaining to that slide is displayed. Students can then submit their own question, which the instructor or TA can later respond to, with the question and answer then incorporated into the appropriate slides, thereby forming an integrated component of the lecture. While no systematic evaluation of this feature has taken place, anecdotal evidence brings up again the scarcest resource of all: time. Professors have expressed reluctance to encourage students to ask questions using this system because they are not sure that they can meet the implied commitment to respond in a timely fashion. Reconceptualising the PAQ as a vehicle for student–student communication rather than simply student–professor communication may be one way to overcome this problem.

The Mini-Presentation feature (deployment April 2001) supports the preparation and delivery of student presentations to provide students with the opportunity to develop their oral communication skills and provide an alternate form of evaluation for professors who have been forced to abandon conventional homework assignments because of the possibility of widespread copying. Students can record (and re-record) presentations in the lab at their convenience. The presentations are then "submitted" and the professor, and eventually other students if that is deemed desirable, are able to review and comment, with the comments anchored to specific points in the presentations. This feature is being formally evaluated in its initial implementation and the results will be used to inform future developments.

1.4. Technical difficulties

While the prime motivating factor for the development of our Intelligent Classroom was to make the professor's interaction with the technology as transparent as possible, there is, unfortunately, no getting away from the inevitability of technical difficulties; it was well understood from the outset that additional technology would not make such problems disappear. Technical failures, stemming, for example, from an overheated projector, or a loose video cable connection, still arise. The most frustrating of these, which we have not been able to eliminate, is the lack of feedback from the main projector, which leaves us unable to determine whether a power on or power off request has completed.

In terms of dependency on any given piece of hardware, responsibility for operation of the projectors, screen, and drapes has been moved from the AMX control hardware to a networked PC, while room lights can now be controlled by either the AMX, the PC, or manually, via the new and much-needed button panel interface we added. Since a serious firmware bug in the earlier controller resulted in sporadic failures, in which the room would become entirely unoperational, this has, in general, been an improvement. While an unannounced change to our network switch configuration last year had a similar effect, this failure was a human error far more than an architectural problem.

During the first 2 years of operation, we experienced the usual frustration of bugs. The first of these arose on occasion when Windows NT failed to release the video frame grabber device after recording a lecture. This resulted in the following lecture not being recorded, without any warning to the instructor. Moving our recording software to Linux corrected this problem but introduced another: the whiteboard software, central to presenting and annotating the lecture slides, would spontaneously freeze for no obvious reason, often half-way into a class.[3] These problems were certainly unhelpful in building instructor confidence in the augmented technology.

In recent months, the day-to-day operation of the classroom has been fairly smooth. There are certainly improvements to be made in areas such as projector state feedback, as described above, and a confusing lag in the response to rotation of the volume knob. However, most of the problems that now arise are due to human factors, such as instructors' mis-specifiying the date of their lecture when uploading class slides, or letting the battery in their wireless microphone run down.

2. The Intelligent Classroom: student reactions

The technological environment of MC13 affects both the students' in-class experience (notably multiple presentation modes and multiple screens) and their out-of-class experience by affording the possibility of access to the annotated slides and lecture recordings as well as the possibility of asking questions at any time. The access logs from Winter and Fall 2000 terms provide quantitative data on how often and when the students accessed the recorded information; questionnaire data provide students' comments on their usage of and reaction to both the in-class and

[3] The latter problem ended up being the result of Netscape's implementation of the Java Virtual Machine, under Linux only!

out-of-class experience. Unfortunately, usable questionnaire data was only obtained in the first term of use; administration of the same questionnaire during the second term resulted in little data, as the students were less than enthusiastic about responding.

Preliminary data analysis from the first term trial with four courses indicated overall positive student reactions, despite numerous technological glitches. Students consulted the lecture material

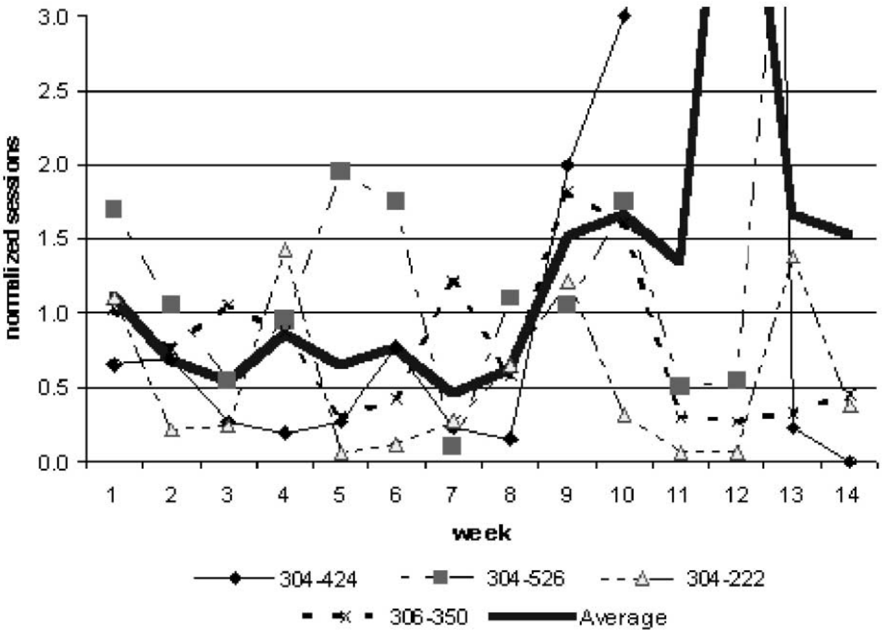

Fig. 2. Number of sessions per week per student for Winter 2000 (average peaks at 66).

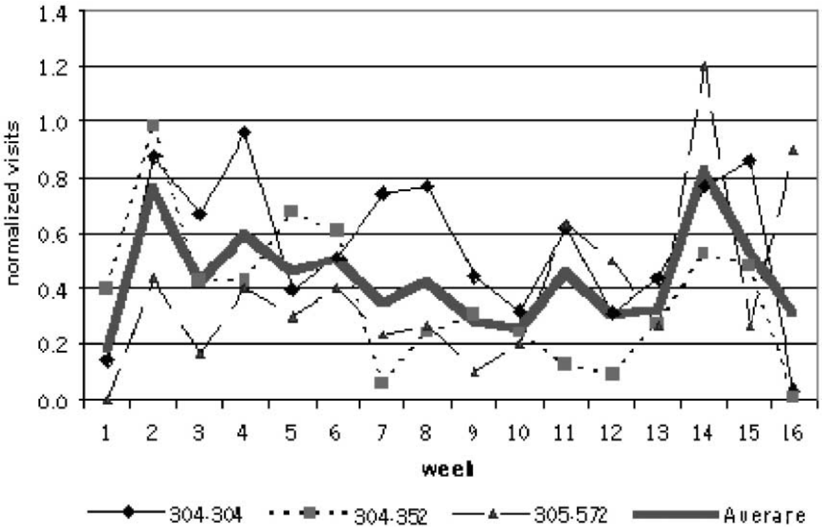

Fig. 3. Number of sessions per week per student for Fall 2000.

an average of once every 2 weeks during the term, with a significant increase just before final exams. Questionnaire data from 90 students indicated a strong positive perception of the impact of the MC13 physical and technological environment on the learning experience.

2.1. Student access to recorded lectures

Every access of every slide and video recording is automatically logged by the system. These data were analysed for four courses in the Winter 2000 term and three courses in the Fall 2000 term. The courses were chosen on the basis of which professors were consistently recording their lectures. The data for the two terms are presented in Figs. 2 and 3; the graphs represent the number of visits per student per week for each week of the term.

The access numbers change from week to week, as one would expect. The peak before the final exam is striking in the Winter 2000 session for the HCI course. In Fall 2000, the peaks in the usage patterns correspond to midterm and finals dates. Students accessed the lectures throughout the term, indicating that what might have initially been a novelty factor continued to provide students with perceived benefits.

The average time per visit (Figs. 4 and 5) is quite varied for the different courses in the different terms. In general, however, the data do not indicate that students simply sat down and watched an entire class, but rather jumped in and out of lectures for brief periods of time.

The purely quantitative results indicate that students accessed the recorded lectures over the course of the term, for relatively short periods of time. The fear, then, that students would simply watch the lectures rather than attending class is not supported by these data. As well, anecdotal evidence from the professors did not indicate any dramatic increase in absenteeism; in many of the large classes in Engineering, an absentee rate of 20% on any given day is not uncommon.

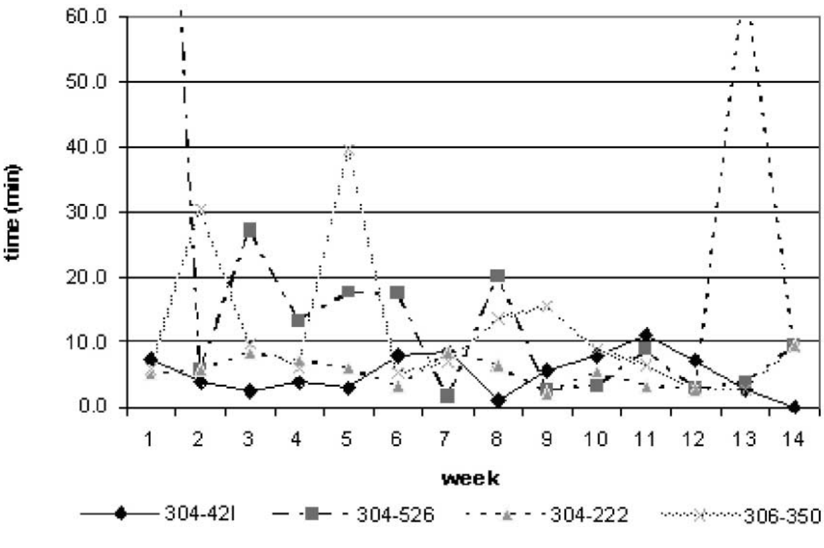

Fig. 4. Winter 2000 average time per visit.

2.2. Questionnaire results

Table 1 provides a summary of the end of course questionnaire results from the Winter 2000 term. Certainly, the overwhelming number of responses indicated a positive impact of the MC13 physical and technological environment on the learning experience. When one eliminates the frustrations caused by technical glitches and crashes, two-thirds of the complaints are eliminated; not surprising, and a fact that leads one to believe that many of the problems that MC13 was experiencing can be attributed to ''growing pains.'' It is also interesting to note that the complaints about technical problems were fairly evenly distributed across the four classes, and the experience of the professor did not seem to be a factor in student reactions.

The single feature most often mentioned as useful was the capability of viewing the previous slide. While the current PowerPoint slide is projected onto a main screen, the previous slide is automatically projected onto a second screen. Students, and the professor, could therefore easily refer to the content of the previous slide when explaining or discussing the current slide. The lecture recording feature was mentioned as the most useful by about 25% of the students responding to the questionnaire; however another 15% mentioned the poor quality of the recordings as the most irritating feature, leading one to believe that if the quality were improved, more than a third of the students would find this to be a useful feature. In fact, we introduced

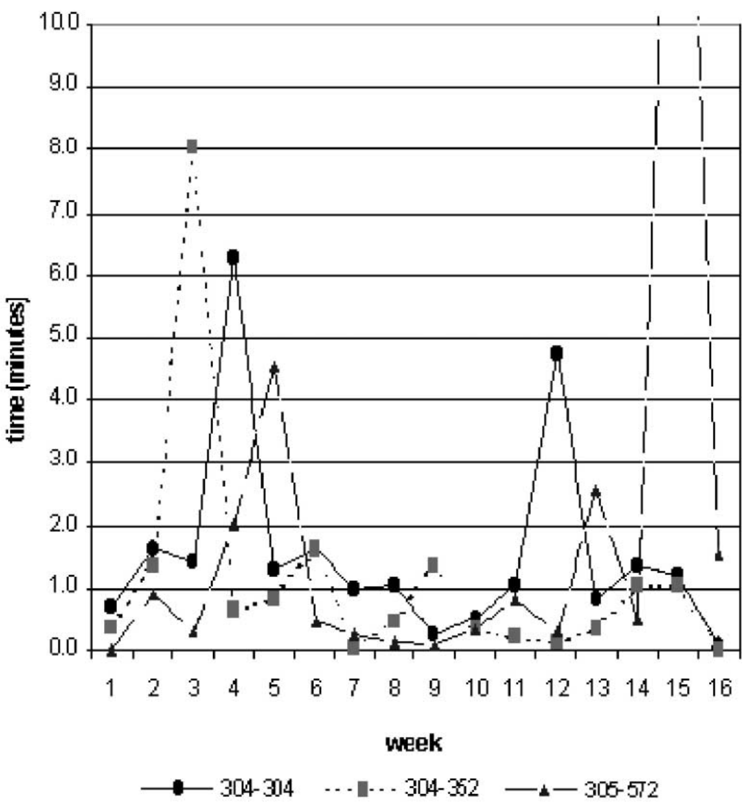

Fig. 5. Fall 2000 average time per visit.

wireless microphones in the Fall 2000 term, resulting in significantly improved audio recording quality. This served to address another point, which, although mentioned by only one student, warrants consideration: the student objected to being recorded. Recording and making publicly accessible a student's interactions in class may well change the nature of some individuals' classroom participation. This is a question that will require serious consideration as the classroom learning environment is re-engineered. However, since with the introduction of the wireless microphones, the students' voices are now effectively eliminated from the recordings, this concern is not presently an issue.

Effect on note-taking on having notes in advance (where applicable[4]) or available for review provoked some contradictory comments. Some students felt that having the material available to them so neatly packaged detracted from their learning experience, *"I learn by writing and doing exercises."* Most students, however, welcomed the opportunity to read notes in advance of class so as not to be in "copy mode" in class: *"The notes were useful. I do not agree that we learn less when we don't take notes. Actually, I think it is quite the contrary. Material is getting more and more complicated. A human brain can't manage to listen, write, sort and understand the information at the same time."* Students who reported taking fewer notes saw this as liberating, allowing them to concentrate more on the content itself. It is interesting to note that the same number of students reported taking fewer notes as those who reported accessing the recordings, suggesting that those who took fewer notes may have used the recordings to supplement their own notes for review. The systematic use of different pen colours in presenting material and annotating the slides was reported to be helpful, a strategy that could also be used in non-technologically enhanced classroom environments.

Table 1
End of course student questionnaire data (responses received from 67 of 198 students registered)

Did the fact that your course was in MC13 change the learning experience for you?	Changed in a positive way: 75	Changed in a negative way: 8	No change: 7
Which features of MC13 did you find most useful? Most irritating?	*Useful: 78* 26: Previous slide 17: Review via web 15: Quality of visual presentations 9: "live" editing/annotations 7: Variety of visual presentation modes 4: Physical environment	*Irritating: 64* 39: Technical problems/Crashes 9: Poor recording quality 6: Physical environment 5: Poor handwriting 2: Lighting changes 2: Professor preparation 1: Being recorded	
Would you like to take another course in MC13, or would you prefer not to?	Yes: 54	No: 8	Neutral: 4

[4] Whether professors' making their notes available prior to class was influenced by their teaching in MC13 is not a question that was explored. However, the students perceived the availability of the notes as part of the classroom environment, and is therefore discussed here.

3. Professors' reactions

Teaching in this kind of environment is not for the faint of heart. As one professor remarked, semi-jokingly, *"I enjoy MC13. It keeps me on my toes because I never know what will go wrong next."* The majority of professors assigned to teach in MC13 make little or no use of the room's features, and simply treat it as they would any other classroom equipped with computer-projection capabilities. But for those four professors who have taken on the challenge of teaching in an unstable environment, they do not want to go back to a regular room. One professor, who was not previously a PowerPoint user, used to prepare his own course notes in Word and then simply write on the whiteboard. In MC13 though, he found that not only was he not spending as much time with his back to the class, both the prepared and extemporaneous content was saved. And even without the recording capabilities, he would use the Classroom 2000 whiteboard software overtop PowerPoint rather than going back to whiteboard alone. After the Winter 2001 term started, this professor made an explicit request to be moved from his assigned lecture room to MC13 because he didn't want to go back to a classical classroom after his MC13 experience the previous term. As will be discussed below in the Impacts section, one professor found that the PowerPoint annotation capability so changed his teaching style that he pushed to make this feature available independent of the room. Although this feature was part of the original Classroom 2000 code, it was not initially implemented. The professor, therefore, had no idea that this was a possibility, and the impetus for the change was directly from the professor.

Other systemic changes to the teaching process have been noted. For example, the fact of uploading the PowerPoint slides before the lecture means that the professor actually has to think about his lecture rather than simply walking in with a box of overheads. And although no professors reported having a student come back to challenge them, there is a raised consciousness about the importance of consistency given that the lectures are all recorded.

The above comments are discipline-independent, but for the professors in Electrical and Computer Engineering (and the students in that area), the relevance of the room itself as an object of study did not go unnoticed. As one professor said, *"The classroom is a living example of what we're trying to teach them about and it screws up like most Engineering projects do. A living lab."*

4. Future work

This kind of project is a perennial work-in-progress, as no sooner has one goal been achieved than two others are identified. One issue of current debate is where efforts should be devoted in improvements to the technical quality. Audio quality was initially a problem with the classroom-mounted microphones. However, the professors now wear lapel microphones, and some students have even commented that it is easier to hear via the Web than live. The question of video quality, however, remains. The video quality is currently far below broadcast standard. But the impact on learning of low quality video is less clear. Although a common assertion is that the poor video quality will inhibit learning, many published reports find this not to be true (Roberts, 1998). Therefore, while efforts to improve video quality may pose interesting technological challenges, if one looks at the potential for improving the teaching and learning experience, this probably should not be a top priority.

There are, however, interesting questions concerning the level of engagement that the recorded lecture can offer to students, in particular, those who are viewing the material for the first time. This interest led to the development of a presenter-tracking algorithm for classroom use, which keeps the camera zoomed on the instructor, and our efforts to record the audio of the students, as well as that of the instructor, in particular when in-class questions are posed. There are, however, concerns of privacy and distraction.

Again, these questions are best considered jointly by the engineers and the pedagogues as the issues are discussed and additional tools developed.

Future refinements and extensions of the PAQ system are topics of significant interest that provoke discussion touching on both technical and pedagogical issues. The PAQ interface was proposed to assist instructors in improving the quality of their teaching by providing a mechanism for student feedback that goes beyond email or discussion group postings. In particular, the questions to the instructor and the response to the student are digitally associated with a particular point (instant) in the recorded class. This means that the instructor, while responding, and the student, while reviewing the response, are provided with the context for their communication (i.e. both have access to the instant in the class about which the student is posing the question). Such a context is otherwise unavailable, expect by manual recollection by both parties in face-to-face meetings. Such provision of context greatly reduces uncertainty regarding the question and greatly improves the efficiency of communication of the response. A software component that would generate the summary of the questions is currently being developed (e.g. *"a lot of students were confused about slide #7"*)—in the future, we may want to tune what kind of information is provided there based on the types of questions that students ask.

As a learning innovation, the system also offers students the ability to benefit from other students' questions and the responses given to them. All students may benefit from all questions asked and answered as the questions are grounded to the content point which sparked them, unlike traditional FAQ resources. The text-based prototype is the first step; the ultimate goal of the design is to provide support for audio and sketch-annotated responses to student questions, through a system no more complex to use than an email program.

4.1. Impact outside of MC13

One software spin-off from MC13 is the development of the PowerPoint annotation capability for use with any digitising tablet. One of the professors, who was already regularly using PowerPoint slides for teaching, became enamoured of the PowerPoint annotation capability (with or without recording) that MC13 offered. He found that because of the annotation capability in MC13, he developed strategies for using PowerPoint for teaching that were distinct from using it for presentations. When faced with the prospect of having to revert to displaying totally prepared slides, he pushed to have this feature available independently of the room. The result: the software configuration was modified to allow instructors to use the system from any PC with network access, rather than being restricted to the MC13 classroom computer. This is a small example of the give and take of technology and teaching.

The Faculty of Engineering is currently in the fortunate position of designing a new building specifically for teaching, the Lorne M. Trottier Building (http://www.mcgill.ca/public/releases/2000/october/itbuilding/). The most dramatic impact of the experience with MC13 can be seen in that the

MC13 environment is now the de facto minimum standard for the classrooms in this new building. The following features that have been identified as being most useful in the current incarnation, with modifications on the current installation reflecting users' input (both professors and students).

- Recording capabilities: audio, video, PowerPoint slides and annotations
- Have regular whiteboard available in addition to projection screen
- Have large electronic whiteboard that is clearly visible from the back of the room; this is desirable for both projection of previous slide and writing
- High quality document reader.
- Manual override for controls that is independent of computer and clearly indicates zones for lighting.
- Reduce distance between professor and farthest student

In closing, it is clear that the technological advances are both driving and being driven by pedagogical needs. Finding the balance between technology and cutting edge, as well as between technology and teaching, is the continuing challenge.

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