ENHANCING GOOD TEACHING PRACTICE IN CONTROL EDUCATION THROUGH HYPERMEDIA INSTRUCTION AND WEB SUPPORT

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Abstract *¾ Poor teaching, especially in math, engineering and science programs, is the most common complaint among students, contributing to dropout rates. Recruitment and retention have long been a concern for leading engineering educators, who recognise that meeting the needs of today's students requires more than the traditional pedagogy. They recommend adoption of student-centered education, and champion good teaching practice. At the same time, information technology is transforming our lives. However, while good teaching does not necessarily mean the use of technology, for technology to be effective, it needs to be a natural extension of good teaching. This paper presents my experiences from four years of hypermedia-assisted teaching of undergraduate engineering courses, where I have successfully used technology to enhance the good teaching practice.*

Index Terms ¾ seven principles of good teaching practice, technology-assisted teaching, learning styles, academic achievement.

INTRODUCTION

In an age of rapidly changing knowledge base, technology-driven globalization, unpredictable job markets, and a decreasing half-life of a university degree, our graduates face an increasingly complex world demanding skills that have traditionally been undervalued in a content-driven teaching environment, prevalent in engineering.

Most academics in this field see themselves first and foremost as content experts, and adhere to the traditional, instructor-centred educational paradigm [1]. Weimer [2] refers to it as “content tyranny”: more is better; we teach content, not students, and if you know it, you can teach it. Yet future engineers need to develop teamwork, leadership, communication and conflict resolution skills, respect for diversity, and an aptitude for life-long, workplace-based learning and holistic systems thinking.

Thus pressures are building to reform engineering education systems in the US [3],[4], UK [5] and Australia [6] to bring them in line with the new workplace realities. Extensive faculty development [4] is needed to equip engineering graduates with the required skills. However, any change must start with a commitment to good teaching. Time after time surveys show that inadequate organization, ineffective presentation, and inaccessible faculty are the most common student complaint and a cause of leaving universities [7],[8]. A recent survey conducted at Ryerson University [9] is quite typical. Questionnaires were mailed out to 2,618 graduating students. With a return rate of 59.5%, the survey was a reliable snapshot of student opinions. While 84% of respondents were satisfied with the overall quality of education they received and 90% considered their professors to be knowledgeable in their fields, more than 50% indicated that the University did not respect them as individuals. Faculty are the main point of contact for the students and thus primarily responsible for such state of affairs. As well, 33% of the respondents thought that their professors did not provide useful feedback on their academic performance, 30% thought their professors' teaching was not intellectually stimulating, 25% did not think the professors communicated well, 25% thought their professors were not well organized, and 18% thought the professors did not encourage student participation in class discussions.

Poor teaching on our campuses is more prevalent that we would like to think. Academics are not required to hold teaching certificates. Faculty development and scholarship of teaching [10],[11] have low priority in most engineering departments, where hiring policies are based on scientific expertise and ability to conduct research. Changing these priorities is difficult, but it has to be done if the engineering education is to maintain its relevance. Championing the principles of good teaching practice is a good start.

SEVEN PRINCIPLES FOR GOOD PRACTICE IN UNDERGRADUATE EDUCATION

Two prominent educators, Arthur Chickering and Zelda Gamson, distilled findings from decades of research on the undergraduate experience [12]. The idea first germinated in 1986, at a retreat for educators at Wingspread in Racine, Wisconsin. In March 1987, the American Association for Higher Education (AAHE) first published “Seven Principles for Good Practice in Undergraduate Education” in its Bulletin. They are: communications with students, teamwork and collaboration, active learning, prompt feedback, time on task, communicating high expectations, and respect for diverse ways of learning.

The Principles have been widely disseminated and although their authors were at pains to stress that they were not a “checklist” for the attention-challenged late 20th century society, part of their appeal is exactly that

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deceptively simple form. However, the enduring popularity of the Principles is based on their truth, as any dedicated educator can attest from their own classroom experiences. They are also universal, as they address the “how”, not the “what”, of good practice in undergraduate education.

TECHNOLOGY AS LEVER FOR GOOD TEACHING PRACTICE

Internet technology can facilitate a shift in the locus of control from the instructor to the learner, by encouraging complex interactions between educators, learners and content through the use of technology [13], and promoting student-centered pedagogy [1],[14],[15]. Asynchronous (time-delayed) communications are singled out as the most notable contribution of technology to the good teaching practice [16]. This paper presents my experiences from four years of using technology to enhance good teaching in two undergraduate engineering courses.

ELE639 is a third year compulsory course in Process Control, and ELE829 is a fourth year professional elective in Systems Modeling and Identification. In instructional design of both courses I opted for strategies based on Felder Model of Learning Styles [17]. Dr. Felder is a longtime proponent of learning that is active, collaborative and experiential, and teaching that is student-centered, accommodating of a wide range of learning styles and fostering problem-solving skills [14].

I use graphics, animations, interactive applets and software simulations in the classroom to help visualize concepts in control theory. Embedded video clips allow me to show behaviors of real-life systems. Courses are supported online through WebCT, a popular web management software. The web sites act as hubs of course activities. My students use asynchronous communications, have online access to lectures and other materials (labs, assignments, tutorials, past tests and exams with solutions, additional reading and external links), course grades, online quizzes and to student presentation areas for web uploads.

Good Practice Encourages Contact between Faculty and Students

“Frequent student-faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through rough times and keep on working. Knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and future plans” [12].

Ever since I started teaching I found that establishing rapport with students is not only mutually enjoyable but also extremely helpful in motivating and guiding them through their learning. My students know they can talk to me on a personal level and I will listen and offer advice if necessary, on issues outside the course as well. I also make a concerted effort to learn their names. It means a lot to the students, who often feel treated like numbers. Moreover, large classes have an alienating effect on students. Laughter is the best way I know to “break the ice”, and technology lends a hand. I start off classes with a funny video clip, or a current movie trailer, downloaded from the web. Once the class is responsive, my lecture begins.

My experiences confirm that asynchronous tools are the best contribution of technology to good teaching practice [16]. “Cyberspace” office hours widened and improved my contacts with the students. Many of them have grueling schedules, juggling studies with full- or part-time jobs and family responsibilities. The 24/7 nature of asynchronous communications offers a solution to lack of time for in-person contact with the instructor. I have also observed that students who make the most postings on the bulletin board or send the most emails are usually not the ones that I get to know well in person. This confirms that the medium encourages students who are otherwise unwilling to ask questions or challenge the instructor directly. They may be shy or there may be cultural reasons for such reticence. In either case, these alternative channels strengthen faculty-student exchanges.

However, asynchronous tools work only if used. I check my email and the bulletin boards at least twice a day, often more, including evenings and weekends, when most students work on their assignments and may require assistance. The bulletin boards allow me to post changes, updates and answer student questions that may be of interest to all. However, the lack of face-to-face contact can be a source of problems. Text-based communications are devoid of body language or intonation. While this may encourage students with less-than-perfect grasp of English, it can also lead to misunderstandings and “flaming.” This is a term originated in newsgroups and describing escalation of sarcastic, rude exchanges and personal attacks. Newsgroups also tend to suffer from an information overload and a high noise-to-signal ratio. I moderate the bulletin boards in my courses to make sure that all students feel free to express themselves online, to ask questions, no matter how trivial, and are not intimidated. I post the rules of the “netiquette” at the start of the semester. The informal tone is OK, but “flaming” is explicitly disallowed, and the discussions should be limited to course-related matters. Creating separate fora for lab sections with different TAs, course management issues, lecture-related questions, etc., helps manage the information flow. The students are responsible for checking the messages and updates online. However, for really urgent messages I use “broadcast” email messages, routed directly to students' personal mailboxes by a simple UNIX command outside of WebCT.

In the end, to function effectively as a guide and mentor I have to maintain a balance between electronic and personal contact. The semi-anonymity of electronic communications may be encouraging to some students who otherwise would never approach me in person. Yet it is quite telling that in exit surveys over 75% of students, while happy to use asynchronous tools, say that they like technology to enhance, but not replace, the in-person contacts with an instructor.

Good Practice Develops Reciprocity and Cooperation among Students

"Learning is enhanced when it is more like a team effort than a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one's ideas and responding to others' improves thinking and deepens understanding" [12].

ELE639 includes team projects in modeling, analysis, design, testing and implementation of control systems. In ELE829, student teams also upload their projects to the web and make classroom presentations. In both courses students use asynchronous tools to communicate with the instructor, and with other students.

However, just putting students in teams is not enough. Collaborative learning occurs when students negotiate conflicts, tutor other team members, and learn how to evaluate their peers' contributions, as well as their own, to the team effort [15], [18]. To achieve this, I introduced peer-evaluation within teams throughout the semester as recommended by Felder [18]. Peer- and self-evaluations are empowering and motivating, and have a proven effect on the learning outcomes [15]. They serve as formative feedback to team members and give them an incentive to mediate conflicts. Critical thinking, teamwork, and evaluation skills are increasingly important in today's engineering environment. This highest level of cognitive skills, as described by Bloom's Taxonomy [19], is difficult to evaluate through conventional norm-based testing, and is best observed in action. Holistic grading, a methodology primarily used in the humanities to evaluate oral and writing skills and effective presentations, is suggested for engineering courses [20], and my experiences confirm its effectiveness. In ELE829, course grades depend entirely on collaborative work over the semester, with no tests or exams. Students develop design skills, but also consensus-building, communication and evaluation skills. Team members collaborate on projects, and in addition to handing in the formal reports, prepare their web versions, sharing files and uploading them to the WebCT presentation areas, as well as make classroom presentations of the results. In ELE829, the whole class evaluates the reports posted on the web, as well as the team presentations, for solutions, clarity and organization.

The mentoring relationship that I am able to develop with the teams provides assurances that frienship, collusive or parasite student marking does not occur [21]. Students learn to feel comfortable with decision-making they have in the course. Collaboration, peer- and self- assessments are empowering and help students become active partners in their own learning process [15]. In ELE829, online materials allow more reliance on self-study supported by the use of asynchronous tools. This leaves more time for mentoring, discussion, hands-on learning in the computer lab and team tutoring, a strategy applied successfully elsewhere [22].

Good Practice Encourages Active Learning

"Learning is is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write reflectively about it, relate it to past experiences, and apply it to their daily lives.They must make what they learn part of themselves" [12].

It is often quoted that we remember 20% of what we hear, but 90% of what we say and do. Engaging students in active learning is a proven and effective educational approach [14]. In my courses, active learning is supported through hands-on real-time experiments in servomotor control. I use technology to enhance it by integrating advanced simulations (MATLAB/Simulink), web-based materials and online quizzes. In ELE829, online materials allowed me to replace most lectures with small group work, most conducive to active learning. In ELE639, this is unrealistic due to a large class size (130-160) and I focused on the use of interactive media to enhance visualization of difficult concepts in control engineering and to better engage the students during the lecture. In the traditional "chalk & talk" environment, with little discussion and a lot of conventional lecturing, students are made passive because their time is mostly spent on writing. My students do not take notes. They can download them as PDF files, read them online, or purchase them in a campus store. Asynchronous access allows for a reflection without which learning cannot occur, and encourages class participation. Thus technology allows me to more time to engage students in discussions. I also use a simple active learning exercise, suggested by Felder: some parts of the text are missing, and are filled out in class while actively problem solving. Cowan [23] refers to "reflection in action", a variation on the Kolb's cycle of experiential learning [24]. I believe that in-class discussions, technology-enabled visualizations, and asynchronous access to course materials allow me to implement this principle in practice.

Good Practice Gives Prompt Feedback

"Knowing what you know and don't know focuses your learning. In getting started, students need help in assessing their existing knowledge and competence. Then, in classes, students need frequent opportunities to perform and receive feedback on their performance. At various points during college, and at its end, students need chances to reflect on what they have learned, what they still need to know, and how they might assess themselves" [12].

I believe in frequent opportunities to provide feedback. Presently, ELE639 students write 8 quizzes, all marked, but I count only the three best for their term mark. Some are written in-class and some are "take-home". This provides a motivational boost and relieves anxiety. Team assignments include two computer projects and an open-ended design project. ELE829 student teams work on 6 tutorials (four best are counted), a major lab project, a web report and a classroom presentation. Students have a secure online access to all course marks. They can also access their learning style assessments. I upload the results immediately after marking, so the students know them before picking up hardcopies of their work.

To be effective, feedback must be prompt, and I keep short return times for all marked materials, typically within days. With increasing enrollments, it becomes a challenge. With this in mind, I started developing online review quizzes. In 2002, students had access to several quizzes providing instant self-assessment. This tool is very popular. Since WebCT makes tracking student progress possible, both individually as well as the overall class performance, it also helps me determine what topics may require an additional review in the class.

I also make use of a "one-minute paper" for formative feedback. At the end of each week's lecture, I distribute index cards and ask students to write on one side the "muddiest point", and on the reverse what they understood to be the salient point of the lecture. I review the cards over the weekend and can provide remedial action if the learning objectives are not being met. Feedback extends beyond students' academic progress. I consult with students and allow their input through the course. I ask for suggestions on handling the process-related issues. At the end of the semester students fill out a detailed, but voluntary, exit survey. The survey results affect course management decisions for its subsequent offerings.

Good Practice Emphasizes Time on task

"Time plus energy equals learning. Learning to use one's time well is critical for students and professionals alike. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty" [12].

Use of technology allows students and faculty to make more effective use of their time. Asynchronous tools and web access break down time and place barriers. An online "at-a-glance" schedule of all course events, deadlines and updates allows the students to better plan their course-related activities. Up-to-date course information can be accessed in a "just-in-time" fashion.

Frequent feedback, enabled by technology directly (online quizzes) and indirectly (in-class quizzes, discussions, one minute papers, etc., made possible by more effective use of time) also helps students with their time management skills. It encourages continuous study rather than a "cram & crash" cycle typical in courses where only one major mid-term test and the final exam are used.

Good Practice Communicates High Expectations

"Expect more and you will get it. High expectations are important for everyone — for the poorly prepared, for those unwilling to exert themselves, and for the bright and well motivated. Expecting students to perform well becomes a self-fulfilling prophecy" [12].

I make sure that students know how important teaching is to me, and how important it is that they do well and develop useful skills. I share experiences from my professional engineering practice. Enthusiasm is contagious and I try to lead by example, setting high expectations for myself for the quality of prepared materials, and timeliness of feedback. High personal expectations and enthusiasm set the standard for the students to emulate.

I take time in the class to evaluate and discuss learning strategies with the students. At the beginning of the course the students fill out a voluntary learning style questionnaire [25], and within days can access the results online. I discuss the different styles and how being aware of them can help modify their learning strategies for greater success. Students are eager to learn more about themselves, and discussing their learning at the beginning of the semester has a motivating effect. As with other activities conducted during the class that are not direct lecturing, I find time to discuss the learning strategies because of the technology-assisted teaching.

Good Practice Respects Diverse Talents and Ways of Learning

"Many roads lead to learning. Different students bring different talents and styles to college. Brilliant students in a seminar might be all thumbs in a lab or studio; students rich in hands-on experience may not do so well with theory. Students need opportunities to show their talents and learn in ways that work for them. Then they can be pushed to learn in new ways that do not come so easily" [12].

Recognition of that diversity led me to broaden my teaching to accommodate different learning styles [26], and technology made it easier to implement. A wider variety of evaluations is also an acknowledgement that different students learn differently. Lab projects, collaborative assessments, self- and peer-evaluations, and presentations do not seem directly dependent on technology. However, asynchronous communications and the web sites indirectly enable diverse course instruction and evaluation strategies.

EFFECTIVENESS OF TECHNOLOGY-ENHANCED TEACHING PRACTICE

I have been developing web-based courseware since 1997 and conducting research on the effectiveness of technology-enhanced instruction in ELE639 since 1999. Following are selected results, as reported elsewhere [26]-[29].

The overall academic achievement in the course has steadily improved since 1997. This coincides with the introduction of web-based lab tutorials in 1998 and of the web support, asynchronous tools, and interactive presentations in 1999. A pilot study was conducted in 1999, followed by a controlled comparison study in 2000, where an experimental group received the technology enhanced classroom instruction and web support, and a comparison group did not. Both groups used email and benefited from collaborative, problem-based, active learning strategies based on experimental work and design using advanced MATLAB/Simulink simulations. The hypermedia-instructed groups performed better, and group differences were statistically significant at 0.01 level (two-tailed) [26]. The comparison groups improved as well, which may be due to an overall improvement in instructional design, as well as to the diffusion effect. This effect occurs when participants from the two groups share experiences of the program. Students are very much aware of differential treatment, especially in the consecutive offerings of the course, when a perception of a "better" course begins to build around one offering. They actively collaborate to achieve the maximum perceived advantage, for example by sharing access to the web site. The diffusion of treatment most likely did take place in ELE639, as the two groups were not, and could not, be isolated. However, since diffusion introduces bias towards "no-difference" results, it did not threaten the internal validity of the study. In 2001, technology-enhanced instruction was extended to all students because withholding treatment from one of the groups in light of the previous positive results would have been incompatible with the objective of increased learning, and simply unethical. Both lecture groups, instructed by different faculty but accessing the same materials, performed similarly [27], and the evaluation concentrated on threats to the study validy [28].

Covariance analysis was used thoughout, with the Prior Academic Achievement (PAA) as a covariate, assessed by the Term Grade Point Average in the semester immediately before the course. Figure 1 shows the residuals, i.e. differences between the expected and the actual performance in the course. F-ratio statistics from ANCOVA were (F=7.155, p=0.009), (F=13.259, p=0.0005), and (F=0.068, p=0.795), respectively [27].

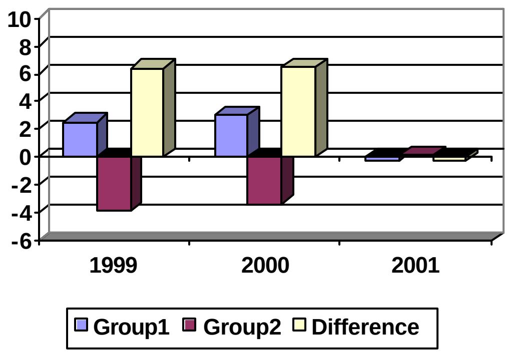

FIGURE. 1
GROUP DIFFERENCES IN RESIDUALS FOR COURSE GRADES IN ELE639

The most noticeable treatment effect was on the students classified as Previously-Below-the-Median (PBM), based on their TGPA. Figure 2 shows that the difference between PBM students and Previously-Above-the-Median (PAM) students in the average Course Grade CG has been reduced in hypermedia-instructed groups, as compared with the similar difference in the TGPA. No such reduction was observed in the conventionally-instructed group in the controlled study in 2000.

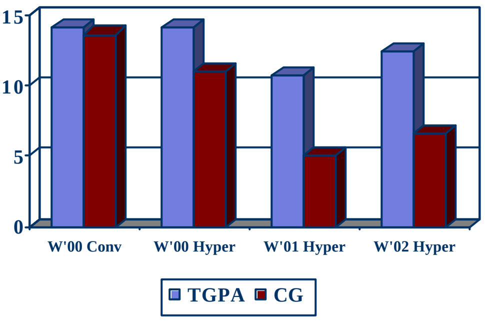

FIGURE. 2
COMPARISON OF DIFFERENCES IN AVG. TGPA AND AVG. ELE639 GRADE BETWEEN PAM AND PBM STUDENTS.

In 2002 the students' performance improved further despite doubling the size of the lecture class into a single group. This may be due to the students' growing ease with the asynchronous communications, improved home access to the web materials, as well as the introduction of online quizzes and "one-minute papers". Exit survey results over the years show that students overwhelmingly support technology-enhanced instruction [29]. Figure 3 shows the preference for a mode of instruction. As well, the enrollment in the elective ELE829 has grown from 12 in 1996 to 44 in 2002 (and 50 pre-registered for 2003). This may be due to the elective's reputation as well as to positive experiences that students signing up for it had had in ELE639.

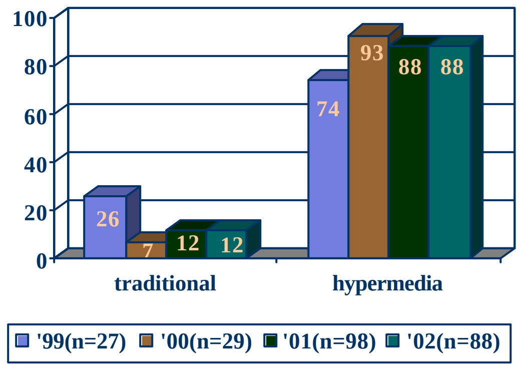

FIGURE. 3
REPORTED PREFERENCE FOR MODE OF INSTRUCTION (IN %)

SUMMARY

My experiences and my research results show that using technology in support of good teaching practice is welcomed by the students, that it provides them with a stimulating environment where they learn more effectively, and that the quality of student-instructor interactions is enhanced, as long as educational and learning goals are kept paramount.

Courseware development does require an investment in time, effort and resources that may be intimidating to a beginner. Yet by now support mechanisms exist at most universities, offering professional advice, training, facilities and help to faculty who want to explore such options. More importantly, use of technology does not have to involve intensive courseware development. Simulation software is already an integral part of most engineering courses. Asynchronous tools require a time commitment but no development work. Simple HTML pages can be easily generated by a word-processing software. Students can be encouraged to use the Web as a research tool, to create, share and post reports online, and to use technology for classroom presentations.

Thus, technology can be used as lever for good teaching practice at any level of complexity that an innovative instructor is comfortable with. However, we should remember that technology is not a panacea for problems in the educational system, and that hypermedia alone cannot equitably replace human interactions that contribute to learning.

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