The Effect of Hypermedia Instruction on Achievement and Attitudes of Students with Different Learning Styles

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Abstract

The goal of this ongoing action research project has been to increase student learning and satisfaction using an innovative approach to instruction, evaluation and interaction with students. A process control course in electrical engineering was redesigned, introducing collaborative, active learning using real-life applications. The course utilizes interactive hypermedia presentations and software simulations in the classroom and takes advantage of the interactive learning environment supported by WebCT[1] software. This includes asynchronous communications (email and bulletin board) and online access to hypermedia materials. The evidence gathered during our empirical study revealed positive effects of hypermedia on students' achievement. Our research also indicated that specific learning preferences are better accommodated through hypermedia-assisted instruction than through conventional instruction.

I. Introduction

The course was redesigned in 1997 to introduce active, collaborative learning, and to increase the exposure to real-life control problems. Student-centered, experiential learning has been shown to have a measurable effect on students' achievement[2, 3]. It also has a positive impact beyond quantitative measures of academic outcomes, such as changes in students' thinking, intellectual development, and personal growth[4]. The course designers therefore placed emphasis not only on the provision of a solid theoretical foundation, but also on the extension of the theory to practice, and on teamwork and communication skills. Real-time experiments in servo-motor control, demonstrations (fuzzy logic and optimal control of a 3D helicopter simulator), realistic design, testing, and implementation using advanced computer simulations (MATLAB and Simulink[5]) became an integral part of the course in and outside of the classroom[6, 7].

Non-technical skills became a larger part of course assessment, as groups of students prepared comprehensive design project reports, with attention paid to improving verbal and written communication skills. Course instructors also encouraged electronic communications via email to increase flexibility of student-instructor exchanges. Since much of the theory of process control relies on understanding fairly complicated mathematical concepts that can be enhanced through visualization, we next turned our attention to technology-enabled instruction and on-line support for the course[8]. Through continuing infrastructure investments over the past five years, many lecture theatres at Ryerson University have been permanently equipped to handle high-end multimedia presentations and Internet access. To take advantage of this, the first author developed an extensive set of hypermedia materials for the use in the course. In the literature, hypermedia is defined as a combination of hypertext and multimedia. Developed lecture materials consist of HTML pages with graphics, animations, and JavaScript interactivity. The presentations also use embedded video clips and Java Applets to help visualize concepts in control theory, and to show behaviors of real-life systems. Presentation technology also allows incorporating software simulations and the Internet into the course lectures. All hypermedia materials used in the classroom are available to students for asynchronous access on-line using WebCT, a powerful web management software package.

Students greeted the introduction of technology-enabled instruction with much enthusiasm. Moreover, in 1999, the first year a fully developed hypermedia version of the course was available, the academic performance of students was significantly higher, compared with those registered in the conventional version of the course[9]. Subsequently, we designed an evaluation component to examine the effects of hypermedia instruction on learning outcomes.

During this time, course instructors also observed that certain types of students performed better in the course than others did. While it is generally accepted that academic ability is the major factor defining success in any academic pursuit, the literature also suggests that individual learning styles might account for some of the differences in learning outcomes[10, 11]. Matching students' individual preferences is not practical in a conventional lecture venue. However, hypermedia-assisted teaching is believed to have a greater potential to do that[10]. As a result, we included investigation of students' learning preferences in our research project.

II Methods

The research project, which took place between January and April 2000, was a comparison study of two different types of learning settings: hypermedia-assisted and conventional instruction. The study involved a quasi-experimental design, with the experimental group (n=54) receiving the hypermedia treatment, and the control group (n=48) receiving conventional lectures. Hypermedia did not replace, it only enriched, lectures, in the experimental group. We focused on researching if hypermedia instruction was capable of accommodating individual differences and learning styles better than conventional instruction, and if student achievement improved.

The students registered in the course represented a fairly homogenous sample in terms of their age and prior experience. Gender differences were not studied, due to a very small number of female students in the program. While random allocation of students to the two groups was not possible due to logistics of the registration process, a random allocation to lab sections was used. To benchmark the comparison study, we compiled a measure of prior academic performance of students enrolled in the course from the university database.

Both instructors teaching the course had comparable expertise, and academic assessment tools (tests, projects, and final examination) were prepared collaboratively so that no course components could be perceived as designed to intentionally favour either group of students. The learning environment for both groups was based on the experiential, project-based instructional design, and included the same level of use of advanced computer simulation tools, and of email. The design of the experiment thus directly addressed problems encountered in many studies from the literature review, such as differences in instructional design, inequitous treatment, different levels of students' ability and prior experience, or small sample size.

The main research hypothesis was that the academic performance of students in the hypermedia instructed group would be better than that of students in the conventionally instructed group. Based on the literature in the area of hypermedia applications in education, we also came up with two specific hypotheses. The first hypothesis was that low achievers would benefit more from hypermedia instruction than from conventional instruction. The second hypothesis was that differences in achievement between different style learners would be minimized in the experimental group, while remaining unchanged in the control group. To help test the hypotheses, we collected information about student learning styles using the Felder-Soloman Learning Style Inventory (LSI)[12, 13].

IV. Results

Terms of Reference

To benchmark the academic performance of each individual student, we used a prior academic performance measure (PAP), as suggested by Wiezel[14]. Students' PAP scores were compiled as the average of the grade in a pre-requisite course and the Grade Point Average for the term immediately before the course. Prior academic performance is a strong predictor of the expected performance in any course, and the expected course grade was assumed to be equal to the PAP measure. Thus, the difference between the actual course grade (CG), and the expected course grade, equal to PAP, may be used to evaluate the student's performance in the course. We defined such difference as the Improvement in the Course (IC):

$$IC = CG - PAP$$

If different offerings of the same course used the same evaluations, were taught by the same instructors, used the same laboratory setup, etc., the mean value of IC would stay at roughly the same level. Due to variance in course characteristics over time, the mean grade in a course, as well as the mean improvement in a course, may vary. However, a good student with a history of performing above average in the past is expected to perform above average in any course. To be able to make more general comparisons, we also defined the Improvement in the Course with respect to the mean (ICM):

$$ICM = (PAP - Mean_{PAP}) - (CG - Mean_{CG})$$

The mean value of ICM for the whole class is always equal to zero, but when two groups are compared, it may be considered a measure of the difference between these groups. Using ICM has an advantage of allowing the comparisons between the course taken at different times, assuming that course marks are not adjusted (bell-curved). To create another common scale of measurement, we adopted a meta-analysis approach[15, 16], and coded all outcomes in terms of the effect size (ES) defined as the difference between the mean score of two groups, divided by the pooled standard deviation:

$$ES = \frac{Mean_{\exp} - Mean_{contr}}{STD_{avg}}$$

The literature recommends that all comparison studies should quote the effect size, because it goes beyond the quest for statistical significance and gets at important clinical or educational differences between groups[17, 18].

Learning Styles of Students in the Study

The Felder Learning Style Model[12, 13] used in this project builds on Jung's theory of psychological types as well as on information processing theory used by Kolb. It avoids the complexity of some other models and it focuses on those aspects of learning styles, which are particularly significant in engineering education. The Felder-Soloman LSI has four dimensions: the Sensing/Intuitive dimension, (how information is perceived), the Visual/Verbal dimension (how information is presented), the Active/Reflective dimension (how information is processed), and the Global/Sequential dimension (how information is understood). Detailed description of the Felder model and the LSI can be found elsewhere[12, 13, 19, 20]. Most students (85%) completed the inventory. Their learning style modalities are shown in Table 1, compared with engineering students at the University of Western Ontario[19], and chemical engineering students at the University of Michigan[20]. The results show that engineering students tend to be Active, Sensing, Visual and Sequential.

Table 1: Learning Style Modalities, in %

Study	Active	Sensing	Visual	Sequential
Ryerson, 2000	53%	66%	86%	72%
Western, 1999	69%	59%	80%	67%
Michigan, 1995	67%	57%	69%	71%

Prior Academic Performance

We computed the PAP measure for both groups, and found normal distributions. There were no statistically significant differences between PAP distributions for the experimental and the control group, as shown in Table 2.

Table 2: Comparison of Prior Academic Performance (PAP), in %

	Mean	STD
Whole Class	70.00	8.50
Experimental Group	69.39	7.81
Control Group	70.74	9.31
t-test (two-tailed)	t=-0.792, df=100, p=0.430	
ES	-0.16	

Impact of Hypermedia on Overall Achievement in the Course

Table 3 shows only the overall results for the course, but the average grades for all course components (i.e. tests, projects, and final examination) were consistently higher in the experimental group.

Table 3: Comparison of Course Grade and Course Improvement between Two Treatment Groups, in %

	CG		IC		ICM	
	Mean	STD	Mean	STD	Mean	STD
Whole Class	66.1	12.47	-3.98	10.11	0.00	10.11
Exp. Group	68.5	11.43	3.14	10.41	-0.82	10.41
Control Group	63.3	13.11	-3.46	8.63	-7.42	8.63
t-test	t=2.047, df=92, p=0.044*		t=3.330, df=92, p=0.001**		t=3.330, df=92, p=0.001**	
ES	0.42		0.65		0.65	

** significant at .01 level (2 tailed)
* significant at .05 level (2 tailed)

The results show statistically significant differences in the academic achievement between the two groups on all three measures. An effect size of 0.3 or higher is considered to be a significant difference between two comparison groups[16, 21]. The effect size of +0.42 means that an average student in the experimental group performed at level 0.42 standard deviations higher than an average student in the control group did. Effect sizes can also be expressed in terms of percentile scores. Approximately 66% of the area of the standard normal curve can be found below a z-score of 0.42. This means that an average, i.e. 50th percentile student in the experimental group performed at the level of a 66th percentile student in the control group on the same achievement examination. The change in group differences before and after the course is visualized in Figure 1.

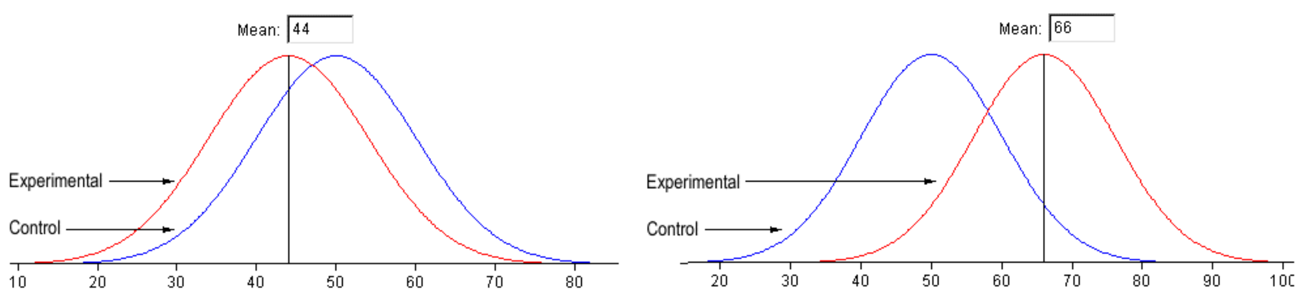

Figure 1: Group Differences before the Course (PAP: ES = -0.16) and after the Course (CG: ES = +0.42)

Impact of Hypermedia on Achievement at Different Levels of Ability

To compare the performance of students at different levels of academic ability, their PAP measures were divided into two equal size groups with respect to the median value - Below the Median (BM) and Above the Median (AM). Table 4 shows the comparison of mean ICM course scores for different PAP levels.

Pearson correlation coefficients between PAP and the final course grade were next computed for each group. The course grade (CG) in the conventionally instructed group is strongly correlated (r

= 0.753, p = 0.0005) with the PAP measure. 86% of students who were low achievers (defined as Below the Median PAP score) going into the course still performed below the class median after the treatment. In other words, students performed similarly in the course and in the past.

However, in the experimental group, the correlation between the final grade CG and the PAP score is only moderate (r = 0.470, p = 0.001). In this group, 50 % of the previous low achievers obtained final grades above the class median. This suggests that the students' performance in the hypermedia course is not as strongly related to their previous academic performance. To investigate this difference in more detail, we next looked at the learning styles of students in the study.

Table 4: Improvement in Course (ICM) for Different PAP Levels

	Winter 2000				
PAP	Exp. Group	No	Control Group	No	ES
Total	+3.14	49	-3.46	45	0.65
BM	+5.51	24	-4.01	22	0.86
AM	+0.86	25	-2.94	23	0.42

<u>Impact of Hypermedia on Achievement at Different Learning Styles</u>

We found Active, Global and Sensing learners over-represented in Below the Median group prior to the course (PAP measure), with 57% of the Active learners, 59% of Global learners and 55% of Sensing learners in that category. In the experimental group these percentages were 61%, 82% and 52%, respectively. Figure 3 shows average improvements in the course (ICM) computed for students with different learning style modalities.

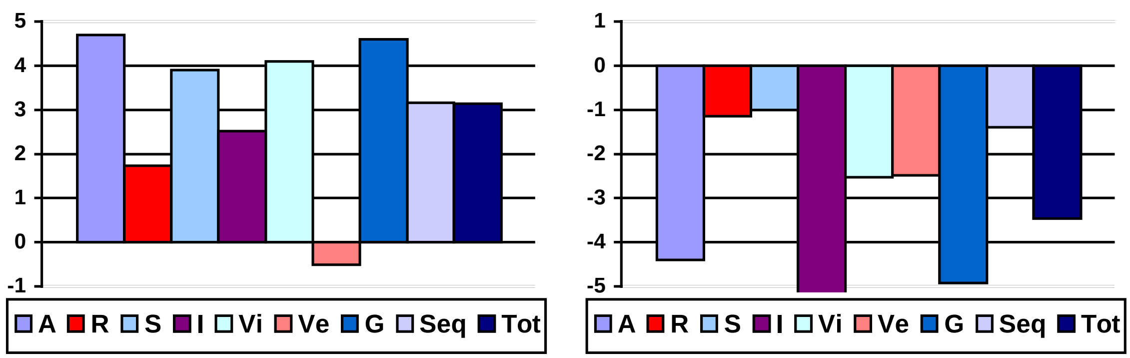

Figure 3: Average Course Improvement (ICM) for Different Learning Styles in the Experimental Group (left) and Control Group (right)

V. Conclusions

Significantly better final course grades and improvement in the course scores were observed for students in the experimental group. The effect size for course grade (CG) differences between the two groups was 0.42. This is considered a moderate significant effect[16, 21, 22]. When the students' achievement was benchmarked with respect to their previous performance (PAP), the effect size for improvement (IC) in the experimental group was 0.65, indicating that an average student in the experimental group improved as much as the 74th percentile student in the control group. The main hypothesis that hypermedia-instruction enhances academic performance was confirmed. The results were consistent with our findings from a previous offering of the course[9]. We also observed that the improvement (IC) in the academic performance in the hypermedia class was greater for low achieving students than for high achieving students (the effect size of 0.86 vs. 0.42, as shown in Table 4).

Studies show[12, 13, 19, 20] that engineering students tend to be Visual, Sensing, Active and Sequential learners, and some of the most creative students are Global. Yet, instruction in engineering departments still tends to be auditory (lectures), abstract (intuitive), passive (little student feedback) and heavily sequential. There is an increasing recognition of the fact that this teaching style does not accommodate students' preferences equally. The mismatches can lead to poor student performance, frustration, and increased dropout rates[13, 20]. Our study showed that Active, Global and Sensing learners were over-represented in Below the Median group prior to the course, consistent with the mismatch between the prevalent style of teaching and the learning styles of students. In the hypermedia-instructed group Active and Global learners improved more than average. In the conventionally instructed group their improvement was below the class average, consistent with the pattern found prior to the course. Sensing learners improved above average in both treatment groups. This is consistent with the experiential learning model adopted for the course.

It appears that the hypermedia instruction was particularly effective for Active and Global students. Visual students in the hypermedia instructed group also improved more than the class average. Verbal learners performed below average in the experimental group, and above average in the control group, but a small size of the Verbal group makes these results unreliable. Our findings seem to support what is asserted in literature, namely, that due to multi-modal attributes involved, hypermedia is more effective in reaching all types of students, and thus helping them to "catch up".

In summary, we can state with confidence that hypermedia in the classroom can effectively enhance the quality of student-instructor interaction, and engage the most vulnerable students who do not thrive in a conventional instruction environment. However, it is quite telling that in their comments, 75% of our students indicated that technology should supplement, and not replace, student-instructor interactions. We should therefore 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.

VI. Future Work

Based on positive results of our research, in 2001, the hypermedia instruction was extended to all students in the course. We shifted our research focus to expanding the framework for the empirical study by including the effect of hypermedia instruction on different levels of cognitive domain, as classified by Bloom's Taxonomy, and on further analysis of interactions with hypermedia among different style learners. We also plan a longitudinal study of ICM scores in the course both before and after the introduction of hypermedia instruction. Instructional design plans for the course include creation of additional hypermedia materials, development of on-line self-assessment quizzes to provide students with feedback at the end of each hypermedia module reviewed asynchronously, adoption of the student project presentations in WebCT, and introduction of elements of peer-evaluation.

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