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Instructional Technology, Learning Styles and Academic Achievement

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Abstract

The paper presents results of an action research project, which took place between January and April 2001, and examined how differences in prior academic achievement of students and in their learning styles affected learning outcomes. All students received hypermedia instruction. The results show that hypermedia allowed previously lower-achieving students to improve their academic performance and therefore reduce the gap between them and their higher-achieving peers. The findings suggest that reducing the gap was a result of hypermedia instruction moderating differences in achievement between students with different learning modalities and accommodating a wider range of learning styles than conventional instruction. These findings were consistent with the previous 2000 study and with the 1999 pilot project, where students in the experimental group received hypermedia instruction, and their achievement was compared with the achievement of conventionally instructed students in the control group. Course website access patterns and a survey of student attitudes towards hypermedia instruction are also discussed. The findings support the use of learning styles as a guideline for incorporation of the hypermedia into the instructional design of the course.

I. Introduction

Background

The study took place in the sixth semester Control Systems course (ELE639) in an undergraduate program in Electrical and Computer Engineering at Ryerson University in Toronto. The course, redesigned in 1997, stresses the extension of theory to practice, with active learning supported by a lab structured around real-time experiments in servo-motor control. Realistic design, testing and implementation, advanced computer simulations, demonstrations, and email communications with instructors are an integral part of the course[1, 2]. To enhance active learning and visualization, the author embarked on developing instructional hypermedia materials. Hypermedia is an outgrowth of hypertext, and provides a non-linear, associative linking of text, images (graphics and video) and sounds. Hypermedia-instruction was first introduced into the course in a 1999 pilot study[3].

The final examination academic performance of the students in the experimental group was significantly higher, as compared with the students registered in the conventional version of the course. A formal evaluation component was then designed, and a rigorous comparison study of two different types of learning settings: hypermedia-assisted and conventional instruction was conducted between January and April 2000. The two hypotheses, derived from the literature, were that hypermedia instruction would improve student achievement, and that it would accommodate a wider range of learning styles than conventional instruction. Both hypotheses were confirmed[4]. Following these findings, continuing the comparison study would have been incompatible with the objective of increased learning. In 2001, the hypermedia instruction was offered to all students registered in the course and the focus shifted to expanding the analysis of interactions with hypermedia among different types of learners.

Hypermedia and Student Achievement

Existing studies on the efficacy of instructional hypermedia are still inconclusive[5, 6, 7, 8]. A recent meta-analysis[7] of 46 studies of the effects of hypermedia on student achievement found 60% of them reporting positive results of hypermedia instruction, while 40% reported no significant differences or negative results. Few of the studies reported in the literature meet even rudimentary scientific requirements for selection, manipulation and control of potential mediating variables[6, 9, 10]. As well, educational researchers face many difficulties in trying to conduct controlled studies in university settings, where threats to validity and reliability are often beyond the influence of the investigator[8, 10]. As a result, often when positive effects of hypermedia on student achievement were identified, a compelling alternative hypothesis could not be rejected[5, 11]. Inconsistent results also underscore the fact that the educational technology itself does not produce learning; and what matters is how it is used. The evidence is accumulating that hypermedia is most effective in the context of student-centered education[12], where it has to be grounded firmly in curriculum goals and incorporated into the instructional process[13, 14].

In the previous stage of the author's study[4], academic achievement of students in the hypermedia-instructed group was significantly better than that of students in the conventionally instructed group. The reported effect size for the treatment effect was 0.65. In the meta-analysis approach, the effect size (ES) is used to create a common scale of measurement[15]. It is defined as the difference between the mean score of two groups, divided by the pooled standard deviation[7, 16]. While ES of 0.3 is considered a moderate but significant effect[16, 17], Liao[7] reported that only 7% of the studies showed ES > 0.5, and the average effect size was 0.41.

Hypermedia and Learning Styles

Chickering and Gamson wrote in their meta-analysis of 50 years of research on principles of good teaching[18] that good practice respects diverse talents and ways of learning, and that students need opportunities to show their talents and learn in ways that work for them. Similarly, Howard Gardner, a professor of education at Harvard university, wrote that students learn in diverse ways and instructors should value and nurture that diversity by attempting to address their individual learning styles and needs in the preparation and presentation of the material they teach[19]. There is recognition that a traditional "chalk & talk" lecture does not accommodate all types of learners, which has lead to an increased interest in research on learning styles. Learning style is defined as a manner in which learners consistently respond to and process information in a learning environment, and is thought to be an individual characteristic that does not change over time[20]. While prior knowledge and prior academic achievement are considered to have strong influence on learning outcomes, personality traits and learning styles are generally considered to be a weak effect[6], and their correlation with the outcomes is not well defined. Studies of the effects of learning styles on achievement are generally inconclusive both in the context of conventional as well as hypermedia-assisted instruction[5, 6]. Dillon and Gabbard, in their extensive review of quantitative research on hypermedia as an educational technology[6] speculate that perhaps the current array of learning style models and inventories was not capable of capturing nuances in a relationship between learning styles and learning outcomes on a statistically significant level.

There is some evidence that because of multi-modal attributes involved, hypermedia may be effective in accommodating a broader range of learning style preferences[5]. A significant amount of research on hypermedia design is being done in the area of dynamic computer-user interface, attempting to match user preferences, simplify navigation and avoid cognitive overhead and disorientation. However, implications of learning styles on hypermedia design should be considered very carefully. Adaptive interfacing uses hard systems approach to a soft systems issue (individual differences and learning process), where few certainties exist. Researchers with background in psychology and education caution against overly relying on psychometric tools in order to differentiate instructional methods to match learner preferences[21]. Matching tasks with students' styles may lead to a danger of denying the students an opportunity to learn a broad range of intellectual skills they need to function in the society[22]. Though the correlation between the learning styles and learning outcomes may be not well defined, a flexible curriculum that accommodates better a broad spectrum of tasks suitable for different preferences can help students achieve their learning objectives more efficiently[22]. Academic improvement in all students is then noted as compared with the cohort taught without differentiation[23]. This supports cognitive flexibility theory[24] and good teaching principles promoted by many educators, including followers of Kolb and Felder learning models[18, 25, 26, 27].

Felder Learning Style Model

In this study, the Felder Learning Model is used[26, 27], along with the Felder-Soloman Index of Learning Styles[28] associated with the model. Detailed description of the model can be found elsewhere[27]. In brief, the model has five dimensions: Processing (Active/Reflective), Perception (Sensing/Intuitive), Input (Visual/Verbal), Understanding (Sequential/Global) and Organization (Inductive/Deductive). Felder recommends the inductive teaching method (i.e. problem-based learning, discovery-based learning), while the traditional college teaching method is deductive, i.e. starting with fundamentals and proceeding to applications. Most students, struggling with an overloaded and mostly traditional curriculum, also prefer this approach. This dimension was therefore removed from the ILS, so as not to provide incentives for a continuing use of the traditional deductive instruction[29]. To increase the support for learners with different individual preferences, Felder advocates a multi-style approach to science and engineering education[27] and incorporation of active, experiential, collaborative and student-centered learning[23]. This approach, along with fostering implementations of technology to enrich the teaching and learning process, has long been advocated as an effective learning environment for engineering education[12, 13, 14].

The Felder model focuses on aspects of learning styles significant in engineering education, and assembles a learning preferences profile of a group of students. This provides a valuable insight into how teaching strategies can be modified to broaden their appeal to a larger cross-section of the student population. Equally importantly, the dimensions of the model can be directly related to the instructional design of hypermedia materials. Synchronous and asynchronous hypermedia can thus be better used to lessen the reliance on lecturing[30], to increase student participation, to support visualization and laboratory experimentation[31], and to encourage reflection[32], all necessary ingredients of the learning process.

Learning Styles in Engineering and their Implications

Personality traits and learning styles are distributed differently among practising professionals and students in different fields. A possible explanation for the differences is that learners who exhibit certain preferences are drawn to a particular field. Engineering students tend to have a preference for Active, Sensing, Visual, and Sequential learning and a significant proportion, often some of the most creative students, tend to be Global[4, 27, 33, 34, 35]. These preferences tend to be higher than among the population at large. For example, among American high school students, 60% are reported to be visual dominant learners[19], while the above studies identified 70% to 90% of engineering students as visual learners.

Engineering faculty are more Intuitive and Reflective as well as more Sequential than their undergraduate students[27, 34]. Despite the current trend to promote learner-centered educational paradigms embracing elements of constructivist philosophy, active, collaborative learning and technological innovations[12, 13, 14], instruction in engineering departments still tends to be Verbal ("chalk & talk" lectures), Intuitive (abstract theory), Reflective (little student feedback) and heavily Sequential (lack of "big picture" emphasis). Graduate students also demonstrate a tendency to more closely align with the faculty learning preferences and attitudes, indicating a presence of what Smith & Waller[12] refer to as a vicious cycle where students who do well in a traditional environment go on to become academics themselves and perpetuate the cycle. Students who do not learn well in such environment are disenfranchised and are more likely to do poorly and even to drop out[12, 27, 34]. Studies show that lower level students exhibit a wider distribution of learning style preferences than upper level students[34, 36]. The shift in the distribution of learning styles between freshman and senior classes indicates that some learning styles may not be well supported by the traditional education model.

Learning Environment outside the Study

Courses in the fifth semester, immediately preceding ELE639, represent a mix of math, basic science and engineering science subjects. Teaching is instructor-centered, relying on a traditional "chalk & talk" lecture format, and have small experiential components or none at all. By the fifth semester students will have been exposed to simulation software packages (PSPICE and MATLAB), C programming and UNIX environment, and have access to the networked computing environment, Internet and email. Yet none of the courses utilize asynchronous learning tools (email, WebCT) for e-counseling or course support, and their online presence is minimal, typically an information/course management page. These courses thus represent what is usually referred to as a conventional, or traditional, learning environment[12, 13]. From the sixth semester on, the program emphasis is on engineering science and engineering design, and on more experiential learning, with labs accounting for 50% of contact hours. However, lectures are still offered in the traditional "chalk & talk" format, and courses have minimal online support and no electronic communications beyond a sporadic use of email.

II. Methods

Instructional Hypermedia

The author opted for a mix of components and instructional strategies appealing to different preferences in a balanced way, and used the Felder model of learning styles as a guideline for incorporation of the hypermedia into the instructional design of the course. Lecture materials consisted of HTML pages with graphics, animations, and JavaScript interactivity. Presentations used embedded video clips, Java Applets and software simulations to help visualize concepts in control theory, and to show behaviors of real-life systems. The course was supported online through WebCT, a popular web management software package. WebCT features utilized in the course included asynchronous communications (email and bulletin board), online access to all lecture materials, supplemental materials (external links, lab and assignment tutorials, past tests and exams), and a secure access to course grades.

The multimedia components (graphics, video, computer simulations and interactive Java applets), used to enhance visualization in the course (also available on the website) aimed at the Visual, Active and Sensing modalities. Students did not take notes during the hypermedia lectures. Rather, they obtained word-processed lecture notes before coming to the classroom and could download any additional textual information from the website. This was designed to allow them to reflect on the topic (Reflective, Intuitive modalities), and to participate better in the class discussions (Active, Verbal modalities), rather than being busy copying down notes. To engage Active students, the word-processed notes were in a format of an "active workbook", where some parts need to be completed in the class. Availability of the class notes, as well as of the website, appealed to Reflective, Intuitive and Verbal students. A majority of engineering students are

Sequential, and a typical flow of instruction in a conventional lecture is also sequential, thus reinforcing a quality that does not serve an engineering professional well. The ability to see a "big picture" and overall connections fosters creativity and problem-solving skills and should be encouraged (Global modality). The hypermedia format and the supporting course website made it easier to use the "big picture" overview and summaries in the lectures and to detract from a sequential flow without a fear of not being able to cover all the required material. The structure of the website also allowed either a linear review of the material or, through the use of frames, browsing the site and an overview, thus appealing both to Sequential and Global modalities.

Study Design

In the 2001 study, all students registered in the course received hypermedia instruction. Due to logistics of the registration process, the course has historically been offered in two lecture groups taught by different instructors. A discussion of possible effects of instructor differences on the outcomes, as well as of other threats to the validity of the study is provided elsewhere[37]. Since both groups received the hypermedia treatment in 2001, and since having an adequate sample of different learning style modalities was important to improve robustness of the analysis, a single group design was assumed.

Student participation in the study was voluntary, and all participating students were asked to sign an informed consent letter. The students were not exposed to any risks or reprisals for refusal to participate in the study. The participation rate was high, with 119 students (93%) filling out the Felder-Soloman Index of Learning Styles, and 95 students (74%) completing an exit survey. A 41-item exit survey, designed to assess students' attitudes towards hypermedia instruction, used the four-point Likert scale and contained positive as well as negative statements (reversal items). Subsequent survey analysis showed strong internal consistency of the scales, with Cronbach alpha of 0.86. Course grades of students participating in the study were entered into a database for statistical analysis, together with the results of the ILS, the exit survey and the tracked website access patterns. These included a number of page hits, percentage of web pages seen, a number of bulletin board postings read, and a number of emails sent. Student achievement, a primary dependent variable, was evaluated through standard academic assessments, and defined by an overall course grade CG. To benchmark the study, a measure of the previous academic achievement (PAA) of students enrolled in the course was compiled from the university database.

Three specific hypotheses were tested. The first hypothesis was that previously low-achieving students would benefit more from hypermedia instruction than previously high-achieving students. The hypothesis was derived from the literature and from the 2000 study. The literature suggests that low learner control hypermedia environments may be beneficial for learners with lower previous knowledge or low achievement record[6, 38, 39]. In environments with high levels of learner control, poor students tend to be overwhelmed[40, 41]. The synchronous use of hypermedia in the classroom constituted the learning environment with little learner control, since despite student participation, the instructor controlled the flow of the lecture. This suggests that hypermedia classroom instruction, and a website review patterned on it, could be particularly effective for students with lower previous achievement.

Because of its multi-modal attributes, hypermedia instruction is asserted to be more effective in accommodating a wider range of individual differences and in reaching all types of students and thus improving overall achievement[5]. Results of the 2000 study[4] supported that assertion. To further test it, the second hypothesis in the study was that differences in achievement between different style learners would be minimized. The third hypothesis, that there would be significant differences between the patterns of the web usage between the previously low-achieving and the previously high-achieving students, was also derived from the literature. It is asserted that learners with higher previous achievement feel more comfortable with the medium, and tend to do equally well in environment with low as well as high levels of learner control[42, 43]. This suggested that they would have higher website access levels.

III. Results and Discussion

Terms of Reference

Student's previous academic achievement is a strong predictor of the expected performance in any course and of the expected course grade[44, 45] and it can be used to benchmark the study. In reporting results of the 2000 study[4], students' PAA scores were compiled as an average of a pre-requisite course grade and of the Grade Point Average for the term immediately before the course, as suggested by Wiezel[44]. The term GPA was an average of final grades in six courses (four engineering courses, one math course, and a liberal studies elective). One of these courses, the pre-requisite in Signal and Systems, introduces most of the analytical tools and concepts expanded on later in ELE639, and has been taught in a large lecture group by the same instructor for the past several years. Thus, the pre-requisite course grade (PRG) could provide a consistent additional reference for discussion of the student achievement. However, PRG accounted for 58.3% of the PAA score and thus was too strongly correlated with it to allow any meaningful analysis. The PAA benchmark was therefore modified in the 2001 study to represent the TGPA score only, as a 0-100 scale, using the following formula:

$$PAA_{0-100} = (TGPA_{A+=4.33} - 0.667)\cdot 11.45 + 50$$

This empirical formula was arrived at to reflect as close as possible the standard guidelines used when converting 0-100 percentage scores into letter grades and GPA scores. The change allowed the analysis of the PRG measure, as it now accounted for only 16.7% of the PAA benchmark. Two additional measures of the student achievement were also considered - a cumulative grade point average CGPA and a sixth semester term grade point average (STGPA) without the course in the study (ELE639). CGPA was an average of 26 courses over the five semesters prior to ELE639. STGPA was an average of five courses offered in the sixth semester, concurrently with ELE639. The PAA, CGPA, PRG and STGPA scores reflected student learning in a conventional "chalk & talk" lecture format, as described in the section above.

Random selection into lecture groups was not possible and existing (intact) groups were used. However, because the students were originally randomly assigned into their sections upon registering at the university, the groups were assumed to have been nearly equivalent from a probabilistic point of view. A one way analysis of variance (ANOVA) was employed to analyze differences between the two lecture groups in the PAA scores, used as a proxy pre-test in the study. Analysis of covariance[46] (ANCOVA) was employed to assess differences in the course grade CG. Comprehensive test grades that PAA comprised of, minimized measurement error. Because of that and of the probabilistic near-equivalency, it was assumed that the analysis of covariance would be free of bias. The PAA score was used as a covariate to compute the expected course grades and residuals. The residuals represent a difference between the actual scores and the expected scores, based on the PAA variance. The mean value for the residuals is always equal to zero, but they can be used to identify groups performing better or worse than expected and thus provide a measure of group differences. As in the previous study[4], to assess the level of achievement prior to the course, two equal-size populations of students were defined using the median PAA score; Previously Above the Median (PAM), and Previously Below the Median (PBM). Similar Above the Median (AM) and Below the Median (BM) groups were defined for CG, CGPA, PRG and STGPA measures.

Learning Styles of ELE639 Students

Learning styles of students in the course have been assessed using the ILS instrument since 1999. Distributions, including the year of the study (2001), are shown in Table 1. The distributions were similar in each of the years when data were collected, and students registered in ELE639 tended to be Active, Sensing, Sequential and overwhelmingly Visual. This is consistent with the findings reported in the literature[27, 33, 34, 35].

Table 1: Learning Style Distributions of ELE639 Students

Year	**n**	**Ref.**	**Act.**	**Int.**	**Sen.**	**Verb.**	**Vis.**	**Glo.**	**Seq.**
1999	28	50.0%	50.0%	42.9%	57.1%	17.9%	82.1%	25.0%	75.0%
2000	85	49.4%	50.6%	32.9%	62.1%	15.3%	84.7%	25.9%	74.1%
2001	**119**	**39.5%**	**60.5%**	**33.6%**	**66.4%**	**10.9%**	**89.1%**	**41.2%**	**58.8%**
2002	120	38.3%	61.7%	35.8%	64.2%	11.7%	88.3%	43.3%	56.7%
Total	**352**	**42.1%**	**57.9%**	**35.0%**	**65.0%**	**12.6%**	**87.4%**	**37.2%**	**62.8%**

The style modalities are a continuum, reflecting the fact that we rarely are one or the other, but rather that the way we perceive and process information combines components of the two polarities. Scores indicating the preference can thus be divided into extreme and intermediate categories at each end of a spectrum, with a balanced category in between. Again, the distributions were similar in all years, with a vast majority of the students in balanced and intermediate (Acting, Sensing, Visual and Sequential) categories. Figure 1 shows the combined distributions (1999-2002, n = 352) of the learning style preferences using both the 2-step scale and the 5-step scale.

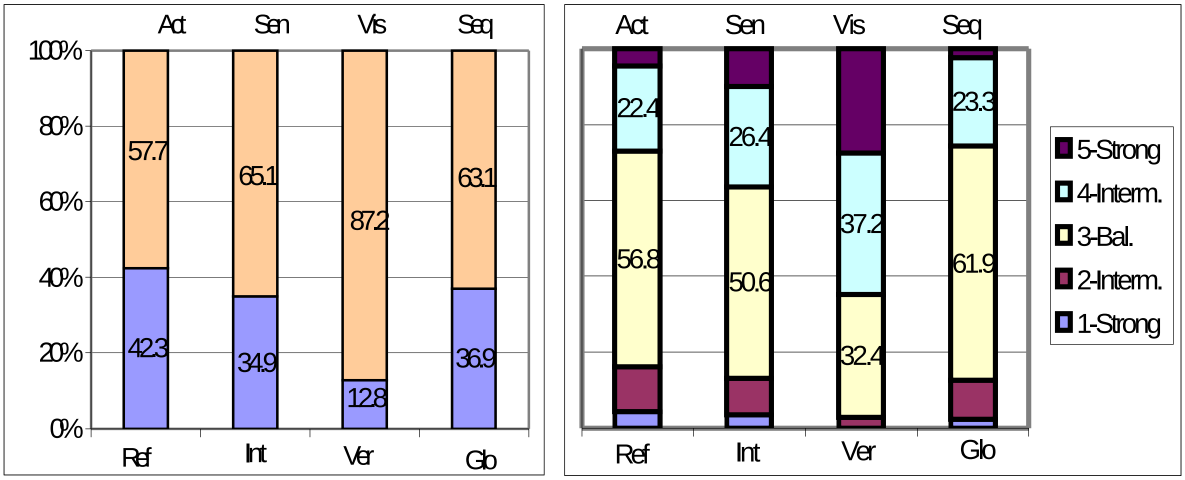


Figure 1: Distributions of Learning Styles (1999-2002): 2 Step Scale (Left) and 5-Step Scale (Right).

It is interesting to note that in four years of data collection (n=352) no students were found to have strong Verbal preference, and only 3% had intermediate Verbal preference, yet close to one-third of all students (28%) showed strong Visual preference. The remaining students were evenly split between intermediate Visual (32%) and balanced Visual-Verbal (37%) preference. This may be a result of a self-selection process, as well as of a filtering effect of the specific program (Electrical and Computer Engineering), where visualization (graphs, flow charts, diagrams, computer simulations) plays a large role regardless of the instructional media used in the classroom. The fact that 50-60% of the students in the remaining categories showed balanced preferences is not surprising in an upper level academic environment, and suggests adaptability and cognitive flexibility of the students. Fewer than 15% of students exhibited strong or intermediate Reflective, Intuitive, or Global preference. Yet, as pointed out before, these students would typically benefit the most from the traditional “chalk & talk” lecture, leaving the needs of a vast majority of the class not as well supported.

Prior Academic Achievement

Average PAA scores were computed for the cohorts in the two lecture groups of ELE639 in 2001 and are shown in Table 2. Group differences were statistically negligible, supporting the assumption of a near-probabilistic equivalence of the two groups and of the validity of the assumed single group design.

Group Differences in Course Achievement

In 2001, both groups were taught using hypermedia instruction. Table 3 shows group differences in the course, including the 1999-2000 results when one group was instructed using hypermedia, and the other was taught using conventional lecture instruction. In the 1999 pilot study, lab projects were not team-marked, and the final exam results are reported in place of the course grade CG. As is customary for the F-ratio statistic from ANCOVA[46], the group means in CG were adjusted for the covariate PAA to allow a more meaningful interpretation of the results.

Table 2: Comparison of PAA (fifth semester) Scores

	1999	2000	2001
Overall Mean	71.39	70.96	73.95
No. of students	94	94	128
STD	8.868	8.693	6.677
Group 1 Mean	72.32	70.34	73.52
Group 2 Mean	70.0	71.63	74.41
ANOVA Statistic	F=1.608, df=1, p=0.208	F=0.516, df=1, p=0.474	F=0.567, df=1, p=0.453
Effect Size ES	0.25	-0.15	-0.13

Table 3: Group Differences in CG (adjusted for PAA), in %

	1999†		2000		2001	
	HYPER	CONV	HYPER	CONV	HYPER	HYPER
No. of students	57	37	49	45	66	62
Pooled Mean	73.51		66.06		75.37	
Group Mean	76.07	69.57	69.17	62.68	75.23	75.53
Residuals	2.516	-3.876	3.0886	-3.3632	-0.1599	0.1702
Pooled STD	11.7282		9.112		6.521	
ANCOVA	F=7.155, df=1, p=0.009**		F=13.259, df=1, p=0.0005**		F=0.068, df=1, p=0.795	
Effect Size ES	0.55		0.71		-0.05	

** significant at .01 level (2 tailed)
* significant at .05 level (2 tailed)
† only final exam data

Figure 2 shows the corresponding residuals. The group differences were negligible when the instructional media were the same (2001), but statistically significant when the choice of instructional media was different (1999, 2000).

<u>Impact of Instructional Media on Different Levels of Prior Academic Achievement</u>

Table 4 shows group differences in mean CG scores from 2001 for the previously higher-achieving (PAM) students, and the previously lower-achieving (PBM) students, with the 1999-2000 data for comparison.

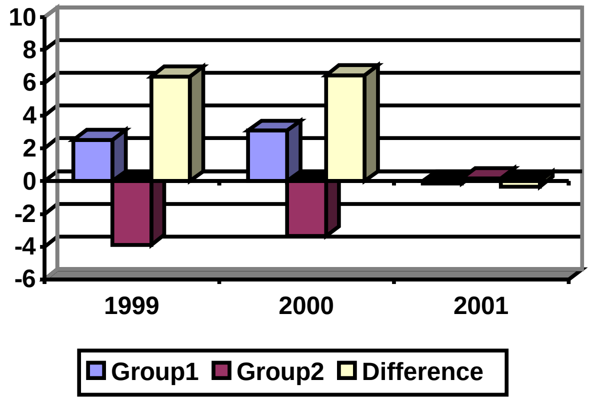


Figure 2: Group Differences in Residuals for the Course Grade

Table 4: PAM-PBM Group Differences in CG (adjusted for PAA)

	1999†		2000		2001	
	HYPER	CONV	HYPER	CONV	HYPER	HYPER
No. of students	57	37	49	45	66	62
PBM Mean	71.08	63.38	63.73	55.58	72.21	73.54
STD PBM	11.5027		9.675		6.389	
ANCOVA	F=5.344 p=0.026*		F=9.040 p=0.004**		F=0.682 p=0.412	
ES PBM	0.67		0.84		-0.21	
PAM Mean	82.17	74.00	75.07	69.05	78.55	77.20
STD PAM	10.4787		8.495		6.579	
ANCOVA	F=7.068 p=0.011*		F=7.078 p=0.011*		F=0.719 p=0.400	
ES PAM	0.78		0.71		0.21	

** significant at .01 level (2 tailed)
* significant at .05 level (2 tailed)
† only final exam data

Figure 3 shows the corresponding residuals for the PAM and PBM groups. The group differences were again negligible when the instructional media were the same (2001), but statistically significant at both levels of previous achievement (PAM and PBM) when the choice of instructional media was different (1999, 2000). As seen in Figure 3, in 2001, the PBM students improved more than the PAM students did. This is consistent with the 1999-2000 results in the hypermedia-instructed group, where the residuals were also larger at the PBM level. However, in the conventionally instructed groups in 1999-2000, the residuals for PAM and PBM groups show that both groups performed similarly worse than expected based on their PAA. This suggests that the hypermedia instruction helped the previously lower-achieving students improve more than their previously higher-achieving peers.

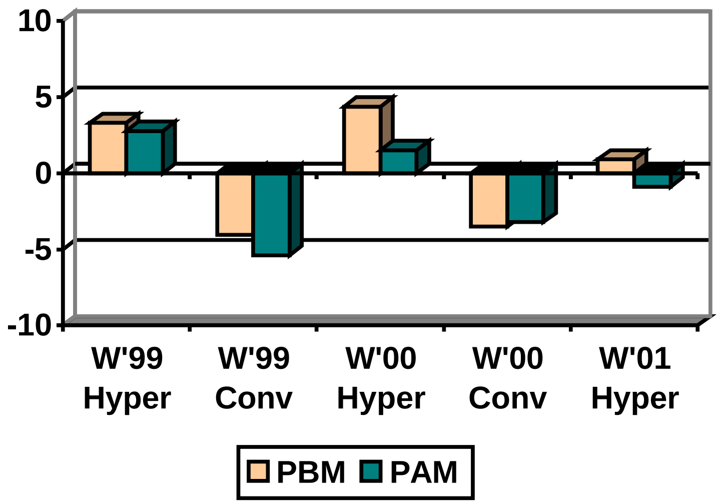


Figure 3: PAM vs. PBM Group Differences in CG Residuals

Table 5 shows distributions among the PBM and PAM groups of students performing at BM and AM levels in ELE639 (1998-2001), and in CGPA, PRG and STGPA (1998-2002). The results in are very consistent. In all the measures describing conventionally taught courses, a vast majority (approximately 80%) of the PBM students performed at the BM level. In other words, the achievement of a vast majority of the PBM students in the courses prior to ELE639 (CGPA, PRG), in conventionally taught sections of ELE639, as well as in the remaining sixth semester courses (STGPA), was similar to their achievement in the past.

Table 5: BM-AM Distributions w.r.t. PBM-PAM in ELE639 in Course Grade CG, and in CGPA, PRG and STGPA

	CG (conv)		CG (hyper)		CGPA (conv)		PRG (conv)		STGPA (conv)	
	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM
PBM '98	79%	21%	-	-	87%	13%	82%	18%	*	*
PAM '98	21%	79%	-	-	13%	87%	18%	82%	*	*
PBM '99	81%	19%	61%	39%	85%	15%	79%	21%	*	*
PAM '99	44%	56%	23%	77%	15%	85%	21%	79%	*	*
PBM '00	90%	10%	52%	48%	73%	27%	71%	29%	70%	30%
PAM '00	40%	60%	18%	82%	27%	73%	29%	71%	30%	70%
PBM '01	-	-	64%	36%	83%	17%	70%	30%	72%	28%
PAM '01	-	-	36%	64%	17%	83%	30%	70%	28%	72%
PBM '02	-	-	*	*	87%	13%	74%	26%	*	*
PAM '02	-	-	*	*	13%	87%	26%	74%	*	*
PBM overall	**82%**	**18%**	**60%**	**40%**	**82%**	**18%**	**75%**	**25%**	**71%**	**29%**
PAM overall	**33%**	**67%**	**29%**	**71%**	**18%**	**82%**	**25%**	**75%**	**29%**	**71%**

* Not Available at the Time of Writing

Only approximately 20% of the PBM students moved up to the AM group in the conventional environment. However, in the hypermedia environment in ELE639 the PBM students showed much higher "upward mobility", with an average of 40% moving up to the AM group. In 2001, 36% of the PBM students moved up. This effect was even more pronounced in the 2000 study, when close to half (48%) of the PBM students in the hypermedia-instructed group moved up to the AM level in ELE639 (Table 5). At the same time, 82% of the PAM students in 2000 (77% in 1999) in the hypermedia-instructed group managed to stay at the same level, as compared to only 60% of the PAM students in the conventionally instructed group (56% in 1999). This percentage was higher than an average "retention rate" of 75% for PAM students in the conventional environment.

As well, the gap between the PBM students and their PAM peers narrowed in the hypermedia instruction environment. As shown in Table 6, the effect size for group differences between PAM and PBM levels in PAA was 1.60 both in 2000 and 2001, and 1.28 for the comprehensive Course Grade in the conventional group in ELE639 in 2000. However, in the hypermedia-instructed groups, the effect size for CG dropped to 0.72 in 2000 and to 0.65 in 2001.

Table 6: PAM-PBM Differences within Groups in PAA and CG (unadjusted) Scores

	PAA		CG		
Year	2000	2001	2000	2000	2001
Mode	CONV	CONV	HYPER	CONV	HYPER
No. Students	94	128	45	49	128
Total	70.96	73.95	66.06		75.37
STD	8.629	6.677	12.474		7.785
PAM	77.91	79.29	73.47	70.46	77.89
PBM	64.01	68.62	64.53	54.48	72.86
PAM-PBM	13.91	10.676	8.931	15.979	5.04
ES	1.60	1.60	0.72	1.28	0.65

Figure 4 shows the gap between AM and BM levels in PRG, PAA and in CG. The gap was similar in PRG, PAA and in the conventional group of ELE639 (2000), but it was reduced by 25% in the hypermedia-instructed group of ELE639 in 2000 and by 50% in 2001. The more pronounced reduction in 2001 is most likely attributable to an increased sample size.

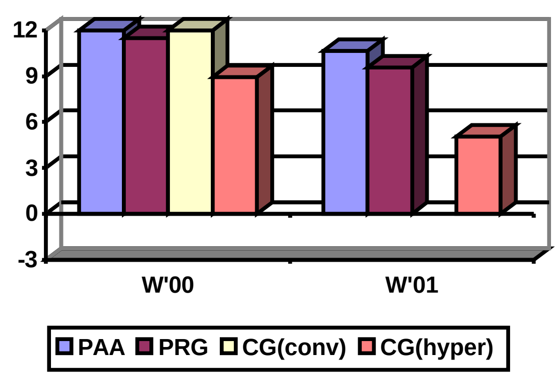


Figure 4: Average AM-BM Differences in PAA, PRG and CG Scores

Impact of Hypermedia on Achievement for Different Learning Styles

Both in 2001 and in 2000, there were some differences in CG, PRG, PAA, CGA, and STPGA scores between different learning style modalities *within groups* using the same instructional media, but none were statistically significant. In the conventional environments (PAA, CGA, PRG, and CG for the conventional group of ELE639), average scores of Sensing and Active students were lower than their Intuitive and Reflective counterparts. The differences between average Sequential and Global scores was the smallest. The largest difference was between Verbal and Visual scores, with Verbal scores much lower than Visual scores in 2000, but higher in 2001. This result could have been random and due to a very small sample of Verbal students (n=13 in both years). Differences in mean CG scores between different modalities were reduced in the hypermedia environment in ELE639.

Figure 5 shows differences in the CG residuals, representing improvement in the course.

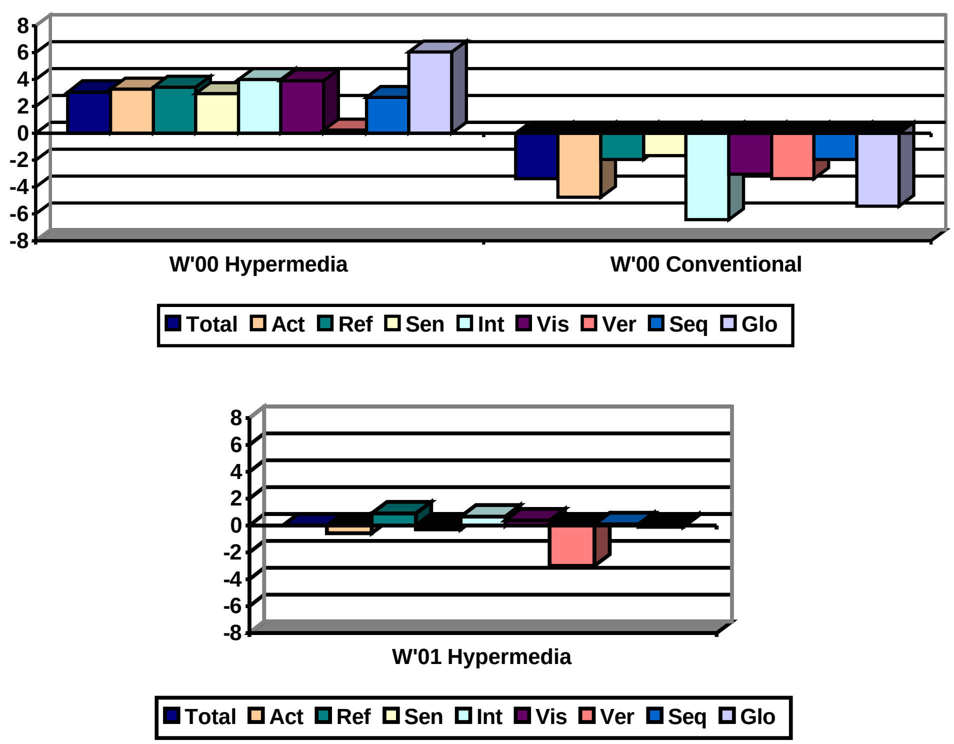


Figure 5: Differences in CG Residuals for All Learning Style Modalities in 2000 (Upper) and in 2001 (Lower).

Differences in improvement between modalities within the hypermedia-instructed groups were very small, except for the Verbal modality (Figure 5, Upper Left, Lower). On the other hand, differences in improvements between modalities within the conventionally instructed group (Figure 5, Upper Right) were much more pronounced. In the 2000 comparison study, differences in CG scores and in residuals *between groups* reached the statistical significance level only for the total group scores (Table 3), but not for any individual modalities. The available sample of students representing different styles in the 2000 comparison study was not large enough to ensure robust statistical analysis (two groups, eight modalities, but only 85 students overall). However, differences between groups did exist for all modalities in 2000. On average, each of the eight modalities in the hypermedia-instructed group outperformed their counterparts in the conventionally instructed group (Figure 5, Upper).

Due to insufficient sample sizes, the analysis of differences in PBM scores or residuals vs. PAM scores or residuals for different learning style modalities was not robust enough to yield any meaningful observations in either of the two years (2000-2001). However, there were some observable differences in distributions of learning styles between the PBM-PAM levels. If the learning style preferences had no effect on the achievement, we could expect that for each modality, 50% of its members would be performing Below-the-Median, while the other 50% would be performing Above-the-Median.

Figure 6 shows differences in numbers of AM vs. BM students in PAA, PRG, STGPA, and CG. For a 50-50 distribution, this number should be very close to zero. The distribution imbalances in conventional instruction environments are most clearly seen in the combined 2000-2002 data (Figure 6, Lower Right) for the prerequisite course (PRG), Term GPA (PAA) and Cumulative GPA (CGPA). Active and Sensing students were consistently over-represented in the BM category, and Reflective and Intuitive students were consistently over-represented in the AM category. The largest imbalances in AM-BM distributions in were found between Intuitive and Sensing Students, where the AM-BM distributions in CGPA were 63%-37% and 45%-55%, respectively. Results for the Visual-Verbal modalities were mixed, and should be interpreted with caution, since the Verbal group was so small. Students with Global modality tended to be over-represented in the AM category.

The distributions for PAA, PRG and STGPA in the two groups in 2000 (Figure 6, Upper) are not entirely symmetrical, because a single median value was used (as group differences were small). For example, there were more AM than BM students for both Active and Reflective modality in the conventional group, and more BM than AM students for both these modalities in the hypermedia group, etc. For CG distributions in 2000, separate median values for both groups were used, because of a significant overall shift towards the AM category in the hypermedia group as a result of the improved performance. In the conventionally instructed group in 2000 (Figure 6, Upper-Left), the AM-BM imbalances did not change much in ELE639 as compared with the other conventional environments (PAA, PRG, and STGPA). However, in the hypermedia-instructed group (Figure 6, Upper Right), the differences were much reduced. Similar effect took place in 2001 (Figure 6, Lower Left).

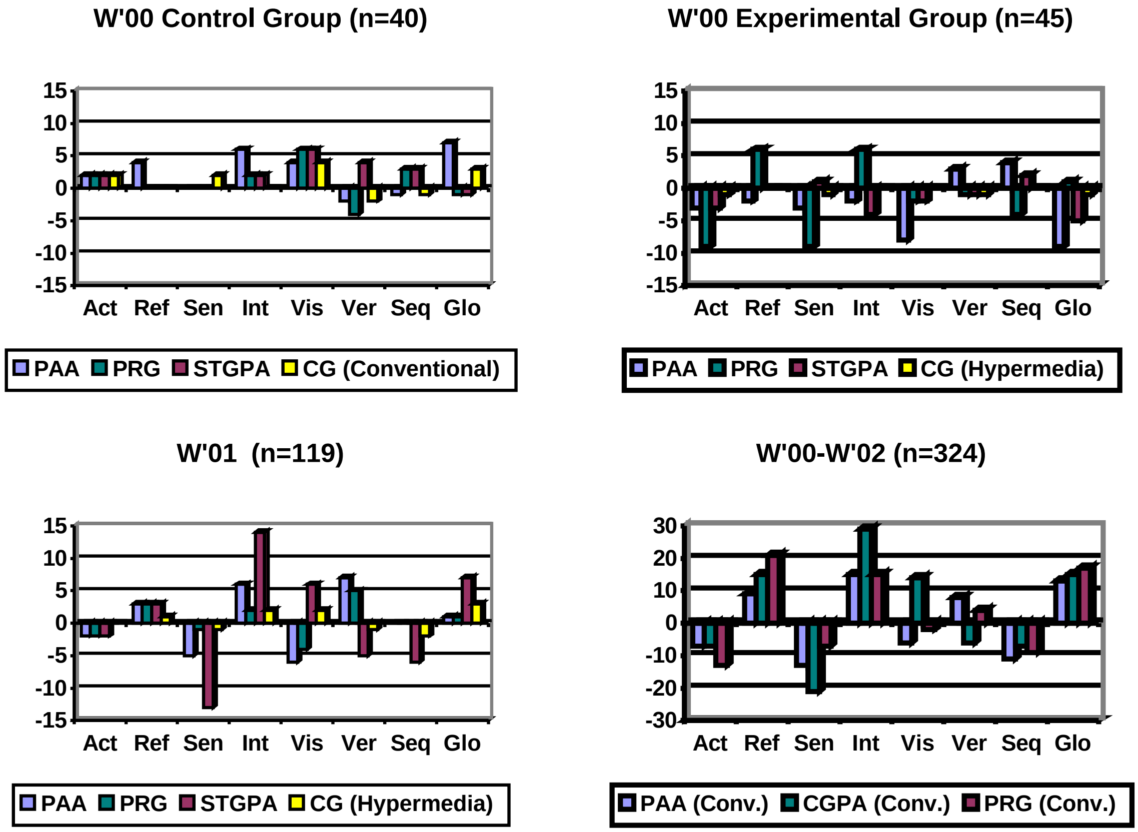


Figure 6: Difference in Numbers of Students between AM-BM Groups in PAA, TA and CG Scores

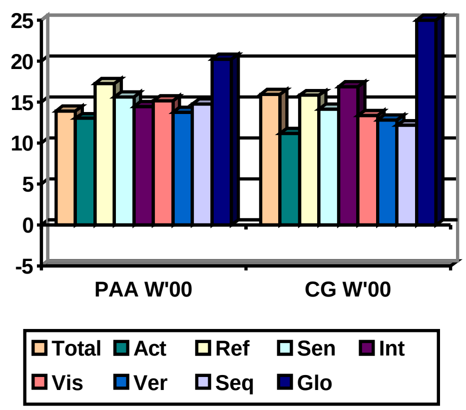
As Table 7 shows, some of the imbalances in the BM-AM distributions among different modalities in the conventional instruction environment reached statistically significant, or nearly significant, levels using the Chi-Square statistic for ordinal data.

Table 7: Chi-Square Statistic for Differences in Distributions at BM-AM Levels in CGPA, PAA and PRG

	Combined 2000-2002		
	CGPA	PAA	PRG
Active-Reflective	$\chi^2=3.313$ p=0.069	$\chi^2=1.739$ p=0.187	$\chi^2=8.571$ p=0.003**
Sensing-Intuitive	$\chi^2=22.726$ p=0.0001**	$\chi^2=6.764$ p=0.009**	$\chi^2=4.500$ p=0.034*
Visual-Verbal	$\chi^2=2.486$ p=0.115	$\chi^2=2.937$ p=0.087	$\chi^2=0.569$ p=0.451
Sequential-Global	$\chi^2=3.552$ p=0.059	$\chi^2=4.138$ p=0.042*	$\chi^2=4.819$ p=0.0028*

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

Figure 7 and Figure 8 show the average AM-BM differences in PAA and CG scores for all learning style modalities. There is little change between the previous achievement and the achievement in ELE639 in the conventional group (Figure 7 Left). A large change for the Global modality is again most likely an artifact of a small sample size. By comparison (Figure 7 Right), in the hypermedia-instructed group, there was a significant reduction in the gap size for Active, Sensing, Visual and Global students. The remaining four modalities had very small sample sizes, and may have been not representative of the overall trend. This seems to be confirmed by 2001 results, shown in Figure 8. In 2001, the gap between AM and BM levels in CG was reduced by 50% in comparison with PAA (Figure 8). This was consistent for all modalities, except Verbal, where the BM average was actually higher than the AM average, resulting in a negative difference. This is most likely a random result, again attributable to a very small sample of students with the Verbal modality.



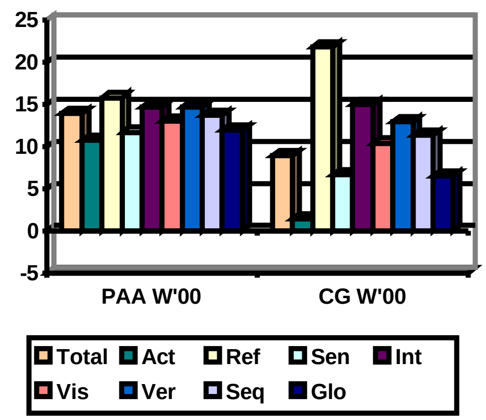


Figure 7: Average AM-BM Differences in PAA Scores and CG Scores in 2000: Conventionally Instructed Group (Left) and Hypermedia-Instructed Group (Right).

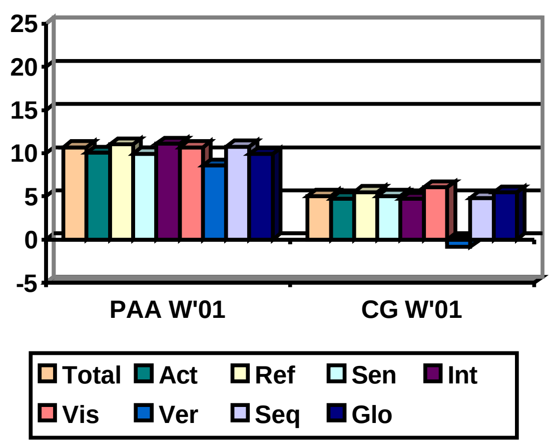


Figure 8: Average AM-BM Differences in PAA Scores and CG Scores (Right) for Hypermedia-Instructed Group in 2001.

Website Usage Patterns

Table 8 shows the total, as well as BM-AM mean values of the percentage of web pages visited, the number of hits on the website, the number of bulletin board postings read, and the number of emails sent to the instructor. There were no statistically significant differences between PBM and PAM groups, with the exception of the number of bulletin board postings read. The previously higher-achieving students (AM in PAA scores) read significantly more postings (F=6.965, df =1, p=0.011). However, as also shown in Table 8, there were statistically significant differences in the website usage patterns between higher achieving and lower achieving students in the course (AM vs. BM groups in CG scores). Pearson's correlation coefficients between the percentage of web pages visited, the number of hits on the website, the number of bulletin board postings read, the number of emails sent, and the final course grade CG are shown for different learning style modalities in Table 9 (2001).

Table 8: Website Usage Patterns in 2000 (n=49) and 2001 (n=128)

	% of Pages	Number of Hits	BB Posts Read	Emails Sent
Winter 00 Total	46.1	597.2	39.7	4.06
PBM	39.41	580.33	31.38	3.63
PAM	52.48	613.40	47.6	4.48
ANOVA (df=1)	F=2.424, p=0.126	F=0.055, p=0.816	F=6.965, p=0.011	F=0.289, p=0.593
BM in CG	28.7	342.0	27.4	0.78
AM in CG	56.2	745.4	46.8	5.97
ANOVA (df=1)	F=11.858, p=0.001	F=9.018, p=0.004	F=9.718, p=0.003	F=12.470, p=0.001
Winter 01 Total	51.2	375.2	55.7	2.15
PBM	48.02	346.72	54.03	2.00
PAM	54.43	403.77	57.39	2.30
ANOVA (df=1)	F=2.696, p=0.103	F=2.612, p=0.109	F=0.329, p=0.567	F=0.113, p=0.738
BM in CG	47.2	330.3	45.4	2.06
AM in CG	55.2	420.1	66.1	2.23
ANOVA (df=1)	F=4.205, p=0.042	F=6.676, p=0.011	F=13.828, p=0.0005	F=0.038, p=0.846

Table 9: Pearson's Correlation Coefficients Between Website Usage Patterns and CG in 2001 (n=119)

	Total	Act	Ref	Sen	Int	Vis	Ver	Glo	Seq
Cover %	r=0.320 p=0.0005 n=119	r=0.317 p=0.007 n=72	r=0.311 p=0.033 n=47	r=0.301 p=0.007 n=79	r=0.311 p=0.050 n=40	r=0.387 p=0.0005 n=106		r=0.389 p=0.006 n=49	r=0.268 p=0.025 n=70
Hits	r=0.284 p=0.002 n=119	r=0.287 p=0.015 n=72	r=0.275 p=0.062 n=47	r=0.341 p=0.002 n=79		r=0.370 p=0.0005 n=106		r=0.371 p=0.009 n=49	
BB Read	r=0.262 p=0.0005 n=119	r=0.229 p=0.053 n=72	r=0.331 p=0.023 n=47	r=0.216 p=0.056 n=79	r=0.339 p=0.032 n=40	r=0.275 p=0.004 n=106		r=0.283 p=0.049 n=49	r=0.246 p=0.040 n=70
Email			r=0.263 p=0.074 n=47					r=0.279 p=0.052 n=49	

For clarity, only statistically significant, or nearly significant, coefficients are shown. With a sample size much larger than in 2000, significant correlations were observed for all modalities except for Verbal. Again, the small sample size is most likely to blame for that. By comparison, in 2000, no correlations were observed for Active and Verbal students, and more correlations were observed for Reflective, Intuitive, Visual and Sequential students than for Sensing and Global students.

Exit Survey

While a detailed analysis of the survey results is outside the scope of this paper, high approval rate for hypermedia-assisted instruction among different learning style groups was reported, as shown in Figure 9. The approval rate for the hypermedia-assisted instruction was overwhelmingly high (96% in 2000 and 87% in 2001). By comparison, in the first year the course was offered in the hypermedia mode (1999), the approval rate was 73%. In 2000, Active, Sensing, Visual and Global students all reported 100% approval ratings. However, the data may be slightly misleading, considering a low return rate (57%) and the small sample (28 valid responses). For example, the 50% approval rate by Verbal students in 2000 is based on a sample of two responses. The 2001 results were more reliable, given a higher return rate (74%) and a much larger sample size (n=95). They show a uniformly high approval rate for all learning style modalities. This confirms that the instructional design of the hypermedia-assisted course appeals to a wide variety of learning styles.

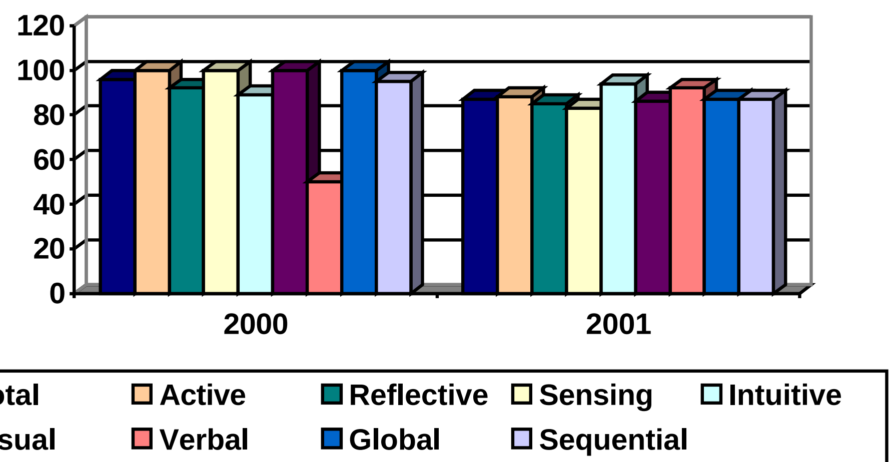


Figure 9: Percentage of Students Who Preferred Hypermedia Instruction over Conventional Instruction

IV. Conclusions and Recommendations.

The learning style makeup of the class (Table 1, Figure 1) was consistent with results of other studies[27, 33, 34, 35]. Fewer than 15% of the students had learning style preferences well supported by the traditional classroom instruction. This confirms the need to expand the repertoire of teaching strategies and instructional media in an engineering classroom, as recommended in the literature[12, 18, 22, 23, 27]. While this may be difficult in a conventional teaching environment, an argument can be made that hypermedia make such an expansion much more realistic.

Group differences in CG were negligible when both groups received hypermedia instruction in 2001 (Table 3). As well, they were negligible before, when the course instructors used a traditional “chalk & talk” lecture instruction. However, both overall and PBM-PAM level group differences were statistically significant in the 1999 pilot study[3] and in the 2000 study[4], when the choice of instructional media was different (Table 3 and Table 4). This supports the conclusion that the choice of instructional method had a strong effect on the achievement, while the effect of instructor differences was negligible[37].

Prior academic achievement is a strong indicator of the academic success, and as expected, the previously higher-achieving (PAM) students still outperformed the previously lower-achieving (PBM) students (Table 4). However, in the hypermedia-instructed groups, the PBM students improved more than PAM students did, while in the conventionally instructed groups, their performance was comparable (Figure 3). As Table 5 shows, there is very little “performance mobility” in the conventionally instructed courses, as close to 80% of all previously low-achieving (PBM) and previously high-achieving (PAM) students performed at the same level (BM or AM). On the other hand, a substantial number of the PBM students in the hypermedia group moved up to the AM group in ELE639 (35% in 1999, 48% in 2000 and 36% in 2001).

The gap between the average scores for PBM and PAM students narrowed (Figure 4, Table 6). The effect size for the difference (ES = 0.72 in 2000 and ES=0.65 in 2001) while still significant, was much smaller than in PAA representing a “chalk & talk” lecture environment (ES=1.60 in 2000 and 2001). The slight narrowing of the gap between PBM and PAM levels evident in the conventionally instructed group in 2000 (ES=1.28) may have been a result of a large lab-based experiential component of ELE639, more accommodating of the prevalent Active modality. The “catching up” effect was uniform for all learning style modalities (Figure 8), with less uniform results in 2000 (Figure 7 Right) most likely due to small sample sizes for the non-dominant modalities. The first hypothesis that hypermedia instruction would be particularly effective in improving performance of previously lower-achieving students was therefore confirmed.

This study has not found any large differences in achievement between students with different learning styles, before or after the hypermedia treatment (Figure 4 and Figure 5). This may support what has been asserted in the literature, that the learning style preferences have a weak effect on the learning outcomes. However, the lack of robustness due to small sample sizes is more likely to blame. As Figure 6 shows, there were imbalances in the distribution of the learning styles (mostly for the Sensing-Intuitive modality, and the Active-Reflecting modality) between BM and AM categories in the conventionally taught courses (PAA, PRG and STGPA scores), and some of them were statistically significant (Table 7). These imbalances disappeared in hypermedia-instructed groups of ELE639, while remaining unchanged in the conventionally instructed group (Figure 6). This observation, combined with the improvements of the previously lower-achieving students and with the smaller gap between the AM and the BM categories of the course grade CG (as compared with PAM and PBM categories in PAA), supports the second hypothesis that the hypermedia instruction minimized differences between different learning styles.

As Table 8 shows, there no significant differences between PBM and PAM groups in the patterns of how the students accessed the website were recorded in 2000-2001. This suggests that previously lower-achieving students were as likely to use the website as the previously higher-achieving students. The third hypothesis was therefore not confirmed. However, the significant differences in access patterns between the AM and BM categories in the course grade CG suggest that the website was an effective educational tool, with students who used the website more, achieving higher grades in the course. Table 9, showing significant correlation between website usage patterns and the course grade for all modalities except Verbal (small sample size), confirms this. So did the results of the exit survey, showing an overwhelming approval of technology-enhanced instruction among all modalities (Figure 9).

In conclusion, the results of the 2001 study confirmed the author's previous findings[3, 4]. They showed that hypermedia instruction was effective in improving overall achievement, and particularly of previously under-achieving students. The results also confirmed that the conventional lecture instruction accommodated only a small segment of student learning preferences, and that the students whose learning styles were not consistent with that instructional style were more likely to be over-represented in the previously under-achieving group. On the other hand, differences among learning style modalities and between AM and BM achievement levels and distributions were much reduced through the hypermedia instruction. This demonstrated that hypermedia was effective in accommodating a wider range of learning style modalities than conventional instruction did, and in moderating differences between those modalities. The study is continuing in 2002, collecting additional data for the analysis of the relationship between learning styles, hypermedia and academic achievement.

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