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The Effect of Individual Learning Styles on Student Outcomes in Technology-enabled Education*

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This quasi-experimental study examined the influence of learning styles on academic performance in two types of learning environments: hypermedia assisted and conventional. Learning style preferences were measured by the Felder-Soloman Index of Learning Styles. In a course offered in a hypermedia-assisted mode to the experimental group, a statistically significant increase in academic achievement was found, as compared with the conventionally instructed control group. The largest increases in achievement were found among students with Active, Sensing and Global learning preferences. These students also expressed the highest rates of approval for the hypermedia instruction and supplemental Web materials. However, there was no significant difference in Web usage patterns between students with different learning styles.

INTRODUCTION

A shift from a traditional to a progressive model of education has led to an increased interest in learners' individual differences. The new paradigm is student-centred, based on inclusiveness, cooperative learning, and encourages diversity. Furthermore, technology is seen as having the potential to enhance the capabilities of the learner and the teacher [1].

The interest in individual differences has recently expanded into the field of engineering education due to an increasing acceptance of student-centred education in this field. In the educational literature, the term *individual differences* encompasses many concepts. They are usually categorised as cognitive styles, personality types or learning styles [2]. Learning styles deal with receiving and processing information within a learning environment.

There are many learning style models, and among the most widely used are:

- Kolb's model.
- Dunn and Dunn model.
- Herman Brain Dominance model.
- VARK model.

Instruments have been developed for each of these four models. Because of an overlap between cognitive styles, learning styles and personality types, a Group Embedded Figures Test for the Field Dependence Independence dimension of cognitive style, as well as the Myers-Briggs Type Indicator for personality type, have also been used to capture learner preferences.

FELDER LEARNING MODEL

More recently, the Felder Learning model was developed [3][4]. This model combines some of the dimensions based on Jung's theory of psychological types (Sensing/Intuition) present in the Myers-Briggs model, with Kolb's information processing dimension (Active/Reflective). It avoids the complexity of the Dunn and Dunn model, and, unlike Kolb's model, which is more general, it focuses on aspects of learning styles that are particularly significant in engineering education.

The model initially categorised learning styles into five different learning dimensions [3]. However, the Index of Learning Styles (ILS) questionnaire devel-

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oped later by Felder and Soloman assesses only four of the model dimensions [5]. These are categorised below.

Model Dimensions

The Sensing/Intuitive dimension deals with the way information is perceived. Sensing learners are practical, oriented towards facts and procedures, and favour information arriving through their senses. Intuitive learners are conceptual, innovative, oriented towards theories and meanings, and favour information that arises internally through memory, reflection and imagination.

The Visual/Verbal dimension deals with the way information is presented. Visual learners prefer pictures, diagrams, graphs, flow charts, experiments and demonstrations, while Verbal learners prefer written or spoken explanations and formulae.

The Active/Reflective dimension deals with the way information is processed. Active learners learn by trying things out, working in a group, and discussing. Reflective learners learn by thinking things through, and working alone.

The Sequential/Global dimension deals with understanding. Sequential learners are linear, orderly, learn in small incremental steps, can solve problems with incomplete understanding but may lack a grasp of the big picture. Global learners are holistic, systems thinkers and learn in large leaps. They work in a more all-or-nothing fashion but once they grasp the total picture, they can often see connections that escape sequential learners.

Detailed descriptions of the Felder model are reported elsewhere [3][4][6]. The literature suggests that approximately 80% of engineering students prefer learning by doing (kinaesthetic learning). This preference is captured both by the Active/Reflective dimension (thinking aspect) and by the Visual/Verbal dimension (experimental aspect).

Application

The Felder model has been gaining popularity among engineering educators and its instrument was chosen for use in this study [4][5]. The ILS questionnaire consists of 44 questions with two possible choices for answers. The score on each of the eight modalities can range from 0 to 11. A difference between scores for two opposing modalities (eg Active score - Reflective score) determines the learner preference along the particular dimension.

The literature indicates that the content itself, and the content-specific style of teaching, prevalent in the old paradigm of education, can have a filtering effect on students. Consequently, learning styles tend to be distributed differently in different fields of study. In the field of engineering, students tend to be Visual, Sensing, Active and Sequential learners and some of the most creative students are Global [6-8].

It is also generally agreed that the conventional teaching style prevalent in schools and universities does not accommodate the preferences of all students equally. Felder recommends developing cognitive flexibility among students by expanding the teaching repertoire of instructors (especially by including more hands-on, cooperative activities) [4][6]. Felder also advocates adopting the *teaching through the cycle* exercises, introduced by Kolb in his experiential learning model [9][10]. These exercises are designed to engage different dimensions of learning styles.

Learning Styles and Hypermedia

Some of the education literature asserts that hypermedia instruction, because of the multi-modal attributes involved, is capable of accommodating a wider range of individual differences in cognitive and learning styles than a conventional mode of instruction. However, there is still little empirical research to support this claim [2].

Findings of studies referring to comprehensive learning outcomes, as measured by academic achievement, are collectively inconclusive both in the context of conventional as well as hypermedia-assisted instruction [11]. This study was conducted to overcome some of the design and sampling problems reported by other studies.

METHODS

The research took place in a senior-level, design-oriented, undergraduate control systems course (ELE639) at Ryerson Polytechnic University in Toronto, Canada. All students registered in the course in the winter 2000 semester were involved. The experimental group (n=49) was exposed to hypermedia instruction while the control group (n=45) was taught conventionally. Random allocation of students to either one of the two groups was impossible due to the logistics of the registration process. However, a random allocation of lab section blocks was used in assigning students to the two groups. This and a total sample size provided a reasonable guarantee of normal distributions of individual differences, even after accounting for the fact that some students did not participate in the study.

Due to faculty loading and scheduling logistics in a

course involving lectures, tutorials and labs, two instructors taught the course. However, both instructors had comparable expertise, and assessment tools have been prepared collaboratively so that no course components could be perceived as designed to intentionally favour hypermedia-instructed students.

The study examined if there was a positive effect of hypermedia instruction (defined as a combination of hypertext and multimedia) on student learning (measured by academic achievement), when compared to conventional instruction. Specifically, it looked at the effect of individual differences (learner ability and learning style) on learning outcomes. The first hypothesis was that learners would benefit more from hypermedia instruction than conventional instruction. The second hypothesis was that differences in achievement between different style learners would be minimised in the experimental group, while remaining unchanged in the control group.

To help test the first hypothesis, a measure of prior academic performance was compiled from the university database and standard academic assessments were used to evaluate academic achievement in the course. To help test the hypothesis regarding learning styles, information about student learning styles was collected using the ILS questionnaire [5]. A 41-item exit survey, designed to assess students' attitudes towards hypermedia instruction, was also administered. The survey used the four-point Likert scale, and contained positive as well as negative statements requiring response (reversal items).

RESULTS

Learning Styles of Students in the Study

Participation rates in the ILS were high: 82% in the experimental group and 75% in the control group. There was no significant difference between the mean PAP scores for those students who filled out the ILS and those who did not (t=0.988, df=100, p= 0.325). Table 1 shows the frequencies for the four learning style modalities of 87 students who completed the ILS are shown in Table 1.

As this first table illustrates, participants of the study are compared with 858 engineering students at the University of Western Ontario, and 143 chemical engineering students at the University of Michigan. Individual learning preferences of ELE639 students were similar to those reported in those two studies [7][8]. However, there was one exception - the Active/Reflective dimension. Their Active, Sensing, Visual and Sequential scores tended to be higher than their Reflective, Intuitive, Verbal and Global scores. Table 2 shows mean and median scores of the study participants for each of the eight modalities, together with the standard deviation.

Table 1: Student learning style frequencies (n=87).

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

Table 2: Felder-Soloman learning style scores (0-11).

Dimension	Mean	Median	STD
Active	5.64	6.00	2.34
Reflective	5.34	5.00	2.33
Sensing	6.34	6.00	2.51
Intuitive	4.62	5.00	2.51
Visual	7.85	8.00	2.02
Verbal	3.12	3.00	2.03
Sequential	6.06	6.00	2.08
Global	4.89	5.00	2.87

Overall, learning preferences of the participants were relatively balanced (median split 6-5 on 0 to 11 scale), with an exception of the Visual-Verbal modality, where a strong preference for the Visual learning style was recorded (median split 8-3 on 0 to 11 scale).

Prior Academic Performance

To benchmark the academic performance of each individual student prior to the registration in the course in which the experiment took place, students' grades in a pre-requisite course and a Term Grade Point Average (TGPA) for the term immediately before the course were accessed from the University database. Next, a Prior Academic Performance measure (PAP) was computed as the average of the pre-requisite grade and the Term GPA, as suggested by Wiezel [12].

A full load in any semester of the programme consists of six courses, and therefore any evaluation biases due to instructor differences tended to be averaged out in the composite TGPA measure. Instructor differences would have been more important in the pre-requisite course, which accounts for 50% of the PAP measure. However, the same professor has taught all students registered in the prerequisite course for the past three years, and therefore the evaluation is not influenced by instructor differences.

The mean value of PAP was 70%, the median value was 70.5% and the distribution was normal. As shown

in Figure 1, there was no significant difference between PAP distributions for the experimental and the control group, (mean values of 69.4% and 70.7%, respectively, t=0.792, df = 100, p=0.430).

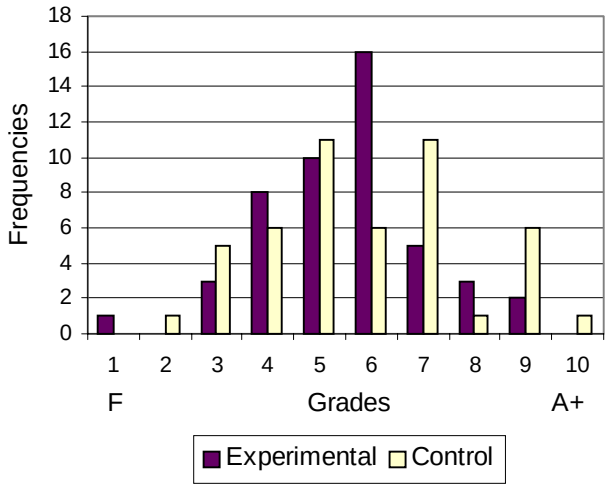

Figure 1: Distribution of PAP scores by group.

To compare students at different levels of academic performance, 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). PAP scores of different style learners were next analysed. In the whole population of the study, students with Reflective style preference had higher PAP scores than students with Active style preference, as shown in Table 3. Similarly, students with Intuitive learning style preference outscored students with Sensing style preference, students with Verbal learning style preference outscored students with Visual style preference, and Students with Sequential learning style preference outscored students with Global style preference.

Table 3: Difference in PAP scores for different styles (Experimental and Control Group combined, n=87).

Style	N=87	% diff.	t-test
Active vs. Reflective	46 vs. 41	-3.3%	t=1.830, df=85, p=0.071
Sensing vs. Intuitive	57 vs. 30	-3.8%	t=2.003, df=85, p=0.048*
Visual vs. Verbal	75 vs. 12	+3.4%	t=1.284, df=85, p=0.203
Global vs. Sequential	23 vs. 64	-0.8%	t=0.323, df=85, p=0.748

When BM and AM groups in the PAP measure were considered (both treatment groups combined), Active learners were over-represented in the Below the Median group prior to the course (PAP measure), with 57% of the Active learners in that group. Global and Sensing learners were also over-represented in the BM group, with 59% of Global learners and 55% of Sensing learners in that category. In the experimental group, the over-representation of Active, Global and Sensing learners in the BM PAP measure group was even higher, at 63%, 82% and 53%, respectively. Data on Visual vs Verbal learners may be unreliable due to the small sample of Verbal learners.

Academic Performance in ELE639

The mean of the ELE639 final course grade CG was 66.1%, the median was 64.5% and the distribution was normal. Distributions for the experimental and the control group, shown in Figure 2, had mean values of 68.5% and 63.4% respectively.

To benchmark the improvement of each individual student, a concept of an expected grade in the course was used [12]. The concept is based on the fact that the PAP score is a strong predictor of the expected performance in any course. Ideally, all courses have comparable difficulty, use similar marking methods, etc, so that the mean grade in each course stays at roughly the same level. In practice, due to the variance in course characteristics, the mean grade in a course may differ. However, a good student with a history of above average performance in the past is also expected to perform above average in other courses, regardless of the actual average grade in the course.

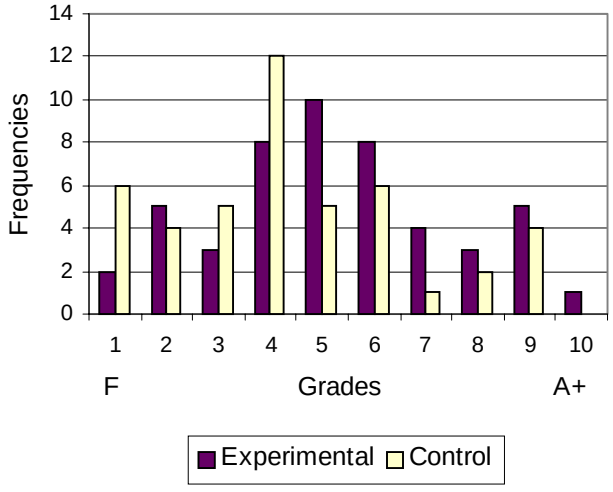

Figure 2: Distributions of ELE639 final course grades by group.

Thus, to be able to make more general comparisons, the improvement in the course with respect to the mean (ICM) was defined as:

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

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 group differences. Using ICM has an advantage of allowing the comparisons between the course taken at different times, if course marks were not adjusted or normalised. As shown in Table 4, differences between the means of CG and ICM scores in the two groups are significant.

Table 4: Comparison of course grades CG and improvement measure ICM between experimental and control groups.

	ELE639 Course Grade CG in %	Improvement w.r.t. Mean ICM in %
Whole Class	66.1	0
Experiment. Group	68.5	3.14
Control Group	63.3	-3.46
t-test (2-tailed) df = 92	t = 2.047	t = 3.330
	p = 0.044*	p = 0.001**

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

Table 5 shows a comparison of the ELE639 performance, measured by the ICM scores for students at different levels of academic ability, as predetermined by their Above the Median (AM) and Below the Median (BM) PAP scores. The correlation between PAP and CG scores was computed next. The PAP score was strongly correlated (r=0.753, p=0.0005) with the CG score in the control group. In this group, previous academic success, as determined through conventional instruction, had the strongest relationship to the academic performance in ELE639.

Table 5: Average ICM score, in %, for different PAP levels.

	Exp. Group	n	Contr. Group	n	t-test (2-tailed)
Total	+3.14	49	-3.46	45	t = 3.330, df = 92, p = 0.001**
BM	+5.51	24	-4.01	22	t = 3.359, df = 44, p = 0.002**
AM	+0.86	25	-2.94	23	t = 1.477, df = 46, p = 0.148

Next, a two-value (AM and BM) measure of the ELE639 performance was also created and compared. Out of 23 students in the control group with Above the Median PAP, 14 (61%) had Above the Median scores in ELE639. Out of 22 students with Below the Median PAP, 19 (86%) still had Below the Median scores in ELE639, and only 3 (14%) had Above the Median scores in ELE639.

In the experimental group, the correlation between PAP and the ELE639 grade was moderate (r=0.470, p=0.001). In this group, out of 25 students with Above the Median PAP, 18 (72%) had Above the Median scores in ELE639, but out of 24 students with Below the Median PAP, 12 (50%) moved up to the Above the Median group in ELE639.

The shift in the experimental group towards higher achievement, shown in Figure 2, as compared with Figure 1 and t-test results in Tables 4 and 5 confirmed the hypothesis that the experimental group performed better than the control group. In particular, the low achieving (BM) group did significantly better in the hypermedia instruction environment. To identify the learning styles of the students who improved most, the specific learning style dimensions were then analysed.

ICM for Different Learning Style Groups

Average ICM scores for different dimensions of learning styles were computed and the comparison between the two groups is shown in Table 6.

Table 6: Comparison of average ICM scores for different dimensions of learning styles in experimental and control groups.

Learning Style	Exp. Group Avg. 68.5		Contr. Group Avg. 63.3		2-tailed t-test
	n	ICM in %	n	ICM in %	
Sensing	26	2.65	23	-0.54	t=1.215, df = 47, p = 0.230
Intuitive	14	2.52	11	-5.49	t=1.900, df = 23, p = 0.070
Visual	34	3.15	32	-1.85	t=2.098, df = 64, p = 0.040*
Verbal	6	-0.48	2	-6.74	t=0.806, df = 6, p = 0.451
Active	22	3.32	14	-4.03	t= 2.037, df = 34, p = 0.049*
Reflective	18	1.73	20	-0.82	t=0.896, df = 36, p = 0.376
Global	9	4.60	11	-4.95	t= 2.028, df = 18, p = 0.058
Sequential	31	2.03	23	-0.80	t=1.102, df = 52, p = 0.275

The largest ICM scores were found for Global (4.60%), Active (3.32%) and Visual (3.15%) students.

It is interesting to observe which learners improved more than the average and which learners improved less than the average for their respective group. Active, Sensing, Visual and Global learners in the experimental group improved more than the experimental group average (equal to +3.14, as shown in Table 5). In the control group, Reflective, Sensing, Visual, Verbal and Sequential learners improved more than the control group average (equal to -3.46, as shown in Table 5). Tables 7 to 9 illustrate the differences between the experimental and the control group for Global, Active and Visual learners, respectively.

As shown in Table 7, Global students in the experimental group had below average PAP scores, with the difference between the two groups significant (as seen in Table 6, t=2.364, df=21, p=0.028). However, their mean course grade CG was above the average for Global students in the control group (t=0.541, df=18, p=0.595), as well as above the average for Sequential students in the control group (t=0.487, df=30, p=0.629). Additionally, even though the Sequential students in the experimental group still outperformed them, the difference was not significant (t=0.249, df=38, p=0.804). The difference in ICM between Global students in the two groups reached p=0.058 in significance.

Table 7: Summary of comparisons for Global students.

	Tot	Glo(exp)		Seq(exp)		Glo(contr)		Seq(contr)	
	Avg	n	Avg	n	Avg	n	Avg	n	Avg
PAP	70.0	11	**66.9**	33	70.9	12	72.6	24	70.5
CG	66.1	9	**67.4**	31	68.6	11	64.2	23	65.4
ICM	0.0	9	**+4.6**	31	+2.0	11	-5.0	23	-0.8
2-tailed test PAP	t = 1.439, df = 42, p = 0.158								
	t = 2.364, df = 21, p = 0.028*								
	t = 1.188, df = 33, p = 0.243								
2-tailed test CG	t = 0.249, df = 38, p = 0.804								
	t = 0.541, df = 18, p = 0.595								
	t = 0.487, df = 30, p = 0.629								
2-tailed test ICM	t = 0.650, df = 38, p = 0.520								
	t = 2.028, df = 18, p = 0.058								
	t = 1.758, df = 30, p = 0.089								

As shown in Table 8, Active students in the experimental group also had below average PAP scores. The difference between Active and Reflective students in the experimental group was significant. Yet their mean course grade CG was above average, and even though Reflective students in the experimental group outperformed them, the difference was not significant. The difference in ICM between Active students in the two groups was significant. Moreover, among Active students in the experimental group, their Active score was positively correlated with the ICM score (r=0.436, p=0.043).

No other significant correlations were found in this study between learning style scores and the ICM scores.

Table 8: Summary of comparisons for Active students.

	Tot	A(exp)		R(exp)		A(contr)		R(contr)	
	Avg	n	Avg	n	Avg	n	Avg	n	Avg
PAP	70.0	25	**67.5**	19	73.0	16	71.4	20	71.0
CG	66.1	22	**66.6**	18	70.4	14	66.3	20	63.1
ICM	0.0	22	**+3.3**	18	+1.7	14	-4.0	20	-0.8
2-tailed test PAP	t = 2.337, df = 42, p = 0.024*								
	t = 1.664, df = 39, p = 0.104								
	t = 1.270, df = 43, p = 0.211								
2-tailed test CG	t = 0.973, df = 38, p = 0.337								
	t = 0.963, df = 34, p = 0.342								
	t = 0.107, df = 40, p = 0.915								
2-tailed test ICM	t = 0.478, df = 38, p = 0.635								
	t = 2.037, df = 34, p = 0.049*****								
	t = 1.382, df = 40, p = 0.175								

As seen in Table 9, Visual students in the experimental group had below average PAP scores. Yet their mean course grade CG was above average. The difference in ICM between Visual students in the two groups was the only significant difference (t=2.098, df=64, p=0.040). The results of comparisons may be unreliable due to the small sample of students with Verbal modality preferences.

Table 9: Summary of comparisons for Visual students.

	Tot	Vi(exp)		Ve(exp)		Vi(contr)		Ve(contr)	
	Avg	No	Avg	No	Avg	No	Avg	No	Avg
PAP	70.0	38	**69.6**	6	71.3	34	71.6	2	63.4
CG	66.1	34	**68.6**	6	66.8	32	65.7	2	52.7
ICM	0.0	34	**+3.2**	6	-0.5	32	-1.9	2	-6.7
2-tailed test PAP	t = 0.459, df = 42, p = 0.648								
	t = 0.991, df = 70, p = 0.325								
	t = 1.064, df = 38, p = 0.294								
2-tailed test CG	t = 0.320, df = 38, p = 0.751								
	t = 0.945, df = 64, p = 0.348								
	t = 1.815, df = 34, p = 0.078								
2-tailed test ICM	t = 0.786, df = 38, p = 0.437								
	t = 2.098, df = 64, p = 0.040*								
	t = 1.287, df = 34, p = 0.207								

Learning Styles and Patterns of Website Usage

Table 10 shows average patterns of Web usage (only the experimental group had access to the supporting Website).

Table 10: Overall average patterns of Web usage: 1 - Web coverage in %, 2 Number of Logins, 3 - Number of page hits, 4 - Number of BB messages read, 5 - Number of e-mails to instructor.

Style	N	1	2	3	4	5
Total	49	46.6	149.9	598.5	40.1	3.8
Act.	25	47.8	158.3	597.2	42.1	3.6
Ref.	19	47.4	152.2	597.6	39.8	4.3
Sen.	28	45.1	150.2	545.9	41.4	4.0
Int.	16	52.0	165.2	687.4	40.6	3.8
Vis.	38	50.5	158.5	640.0	41.5	3.8
Ver.	6	29.7	138.0	327.5	38.8	4.7
Glo.	9	41.2	143.2	564.6	30.2	4.1
Seq.	33	48.3	156.3	584.9	43.0	4.0
BM CG	19	32.1	119.0	448.1	28.0	0.7
AM CG	30	54.9	171.6	691.6	47.0	6.2
2-tailed t-test for BM vs. AM, df = 47		t=2.791 p=.008**	t=2.791 p=.039*	t=1.731 p=.090	t=3.089 p=.003**	t=3.794 p=.0001**

Data for different learning style modalities, as well as for Below Median and for Above Median group in the ELE639 course grade CG is shown. Intuitive, Visual and Active students had the highest average number of page hits, logins and pages read. Verbal students had the lowest coverage, logins and hits, but the highest average number of e-mails. No significant differences were found in Website usage patterns between learners with opposite modalities. However, as shown in Table 10, when students with Above the Median course grades CG were compared with students with Below the Median course grades, significant differences were observed in all patterns of the Website usage, except the number of page hits.

Table 11 shows correlations between patterns of Website usage and the final course grade. When the whole experimental group was considered, positive correlations were found between the course grade and the number of pages viewed (Web coverage), messages read on the Bulletin Board, and the number of e-mails sent to the course instructor.

As seen in Table 11, some significant levels were reached by the Sequential, Reflective, Intuitive, Verbal, Visual and Global students, and additional almost significant levels by the Visual, Sensing and Active students. Results for Verbal and Global students may be unreliable due to small samples.

Learning Styles and Perception of Hypermedia Instruction

An exit survey was administered to students in the experimental group at the end of the semester. The survey participation rate was 66.7%. Table 12 shows percentage of *Agree* or *Strongly Agree* responses of students with different learning styles to items related

Table 11: Pearson's correlation coefficients between patterns of Web usage (n=49) and ELE639 course grade: 1 -Web coverage in %, 2 - Number of page hits, 3 - Number of BB messages read, 4 - Number of e-mails to instructor.

	1	2	3	4
Total 49	r = 0.325*	r = 0.229	r = 0.365*	r = 0.391**
	p = 0.023	p = 0.114	p = 0.010	p = 0.005
Ref. 18	r = 0.644**	r = 0.401	r = 0.489*	r = 0.499*
	p = 0.004	p = 0.099	p = 0.039	p = 0.035
Active 22	r = 0.114	r = 0.170	r = 0.293	r = 0.376
	p = 0.613	p = 0.450	p = 0.186	p = 0.084
Sensing 26	r = 0.351	r = 0.245	r = 0.170	r = 0.332
	p = 0.079	p = 0.228	p = 0.407	p = 0.108
Int. 14	r = 0.393	r = 0.420	r = 0.775**	r = 0.627*
	p = 0.164	p = 0.135	p = 0.001	p = 0.016
Seq. 31	r = 0.502**	r = 0.383*	r = 0.388*	r = 0.375*
	p = 0.004	p = 0.033	p = 0.031	p = 0.038
Global 9	r = -0.276	r = -0.070	r = 0.488	r = 0.714*
	p = 0.472	p = 0.857	p = 0.182	p = 0.031
Visual 34	r = 0.306	r = 0.290	r = 0.273	r = 0.405*
	p = 0.078	p = 0.096	p = 0.119	p = 0.017
Verbal 6	r = 0.961**	r = 0.735	r = 0.895*	r = 0.643
	p = 0.002	p = 0.096	p = 0.016	p = 0.168

to the hypermedia lectures and instruction. Items 1 to 8 were described as follows:

1. Attended 30 or more hours of lectures (out of 39).
2. Online allow for better concentration on the lecture.
3. Use of graphics and interactive applets in lectures help.
4. Use of video in lectures help.
5. Computer simulations in lectures help.
6. Multimedia lectures confusing and boring.
7. Multimedia lectures help in comprehension.
8. Use of multimedia complements the way they learn.

All respondents agreed with item 3. The strongest agreement was found for items 1, 2, 4, 5, 7 and 8, and the strongest disagreement with the (reversed) item 6 was reported by Global learners, followed by Active

Table 12: Exit survey results in % for experimental group - hypermedia lectures (both survey and ILS completed, n=34).

	N	Item							
		1	2	3	4	5	6	7	8
Tot.	35	66.7	88.9	100	94.2	91.7	5.6	94.1	91.2
Act.	17	66.7	**94.4**	100	**100**	**100**	**0.0**	**94.1**	**94.1**
Sen.	23	**75.0**	88.5	100	95.7	91.7	4.2	91.3	91.3
Vis.	30	**71.0**	90.3	100	**96.7**	**96.8**	3.2	**96.7**	**96.7**
Glo.	8	**87.5**	**100**	100	**100**	**100**	**0.0**	**100**	**100**
Ref.	17	70.6	88.2	100	88.2	82.4	11.8	93.8	87.5
Int.	11	54.5	90.9	100	90.9	90.9	9.1	100	90.0
Ver.	4	50.0	75.0	100	75.0	50.0	25.0	33.3	33.3
Seq.	26	63.0	**96.3**	100	92.3	88.9	**0.0**	92	88

and Visual learners. Table 13 shows percentage of *Agree* or *Strongly Agree* responses of students with different learning styles to items related to the Website use. Items 1 to 6 were described as follows:

1. Experienced technical difficulties using materials.
2. Website confusing and difficult to use.
3. Had concerns about their privacy while using the Web.
4. Found the Bulletin Board useful.
5. Found e-mail useful.
6. Liked access to online marks.

Table 13: Exit survey results in % for experimental group -supporting Website usage (both survey and ILS completed, n=34).

	N	Item					
		1	2	3	4	5	6
Tot.	35	16.7	11.1	19.5	86.1	91.7	80.5
Act.	17	22.2	**5.6**	22.2	**94.4**	**94.4**	**83.3**
Sen.	17	**11.8**	17.6	**17.7**	76.5	94.1	76.5
Vis.	23	16.7	16.7	20.8	**87.5**	**95.8**	**83.3**
Glo.	11	18.2	**0.0**	18.2	81.8	90.9	72.7
Ref.	30	**16.1**	9.7	**19.3**	83.9	93.5	77.4
Int.	4	25.0	25.0	25.0	**100**	**100**	75.0
Ver.	26	18.5	14.8	22.2	81.5	88.9	**85.2**
Seq.	8	**12.5**	**0.0**	**12.5**	**100**	**100**	62.5

Global learners, followed by Visual and Reflective learners, reported the strongest disagreement for (reversed) items 1, 2 and 3. Global and Verbal learners, followed by Active and Sensing learners reported the strongest agreement with items 4 and 5. The strongest agreement with item 6 was reported by Sequential learners, followed by Active and Sensing learners. Data on Verbal learners may be unreliable due to the very small sample. Table 14 refers to responses to the question of which method of instruction is preferred (hypermedia or conventional).

Table 14: Learning style preferences in % for hypermedia instruction (both survey and ILS completed, n=34).

	Act.	Ref.	Sen.	Int.	Vis.	Ver.	Glo.	Seq.
%	**100**	93	**100**	90	**100**	50	**100**	96

The table shows a percentage of students choosing hypermedia instruction over conventional instruction, when broken down by different learning style groups. All students with Active, Sensing, Visual and Global learning preferences indicated hypermedia instruction as their preferred instructional method.

DISCUSSION

Significantly better final course grades CG and ICM scores were observed for students in the experimental group, shown in Table 4. An upward shift in the distribution of academic performance in the experimental group was found as compared to the control group, as illustrated in Figure 2. The hypothesis that hypermedia-instruction enhances academic performance was thus confirmed. The results confirmed earlier findings from a previous offering of the course [13]. It was also observed that the improvement (ICM) in the academic performance in the hypermedia class was greater for low achieving students than for high achieving students, as shown in Table 5.

Most of the instruction in engineering schools, including at Ryerson, tends to be auditory (lectures), abstract (intuitive), passive (little opportunity for student feedback) and sequential. The observed patterns of PAP scores (Table 3) suggest that the conventional instruction does not accommodate all learning styles equally, with Active, Sensing and Global students performing below average prior to the course. As stated in the literature [4][8], such mismatch between the conventional style of teaching and the learning styles of the students can lead to poor student performance, professorial and student frustration, as well as compromised student retention.

In the experimental group, Active and Global learners improved more than average. In the conventionally instructed group, their improvement was less than the class average, consistent with their performance prior to the course. Sensing learners improved more than average in both the experimental and the control group. This is consistent with the experiential learning model adopted for the course [14][15].

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 the small sample of Verbal learners makes these results unreliable. The 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 reducing differences in the academic performance among different learning styles. The hypothesis that hypermedia instruction accommodates a wider range of learning styles was therefore confirmed.

There were no significant differences in the pattern of the supporting Website usage, and some positive correlations between the patterns of the

Website usage and ELE639 course grade CG were found for all modalities, as seen in Table 11. The analysis of the Web usage patterns showed that students with low PAP scores in the experimental group used the Website less than students with high PAP scores. However, at the same time, they significantly outperformed their counterparts in the control group. It is therefore concluded that the low achieving students benefited from the structured hypermedia environment (classroom instruction) rather than from the unstructured environment (asynchronous access to the Website).

The Website appears to be an effective supplementary tool for students with all learning style modalities. The correlations between course grade and the Website usage were weakest for Active and Sensing students. It may be an issue that needs to be addressed through instructional design to make the materials more engaging for these particular modalities. Also, the relatively small sample of styles may have affected the results.

The survey results indicated a strong preference for technology-enhanced instruction, as seen in Table 14. An overwhelming approval of all aspects of hypermedia usefulness was reported, as shown in Tables 12 and 13. The preference for hypermedia instruction is particularly strong among Active, Sensing, Visual and Global students, who appear to be not well served by the conventional instruction.

FUTURE WORK

In winter 2001, the hypermedia instruction as well as the Website access will be extended to include all students enrolled in the course. This will allow the study to address issues of group and instructor differences.

Such an increased sample of students receiving the hypermedia instruction and accessing the Website will also improve the power of statistical analysis of Website usage patterns and survey results.

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BIOGRAPHIES

Malgorzata Zywno is a Professor in the Department of Electrical and Computer Engineering at Ryerson Polytechnic University in Toronto, Canada. She received her MEng degree in Electrical Engineering from the University of Toronto in 1990, specialising in control systems. She is currently in a doctoral programme at the Glasgow Caledonian University in Glasgow, Scotland, United Kingdom. Her teaching and research interests include linear, adaptive and intelligent control, as well as system modelling and identification. Since 1997, Professor Zywno has been exploring the implications of technology-aided pedagogy. She has extensive experience in developing multimedia and Internet-based courseware, and has published several papers on engineering education.

Professor Zywno is a Research Associate of the Ryerson Centre for Engineering Education (RCEE) and the Centre for Quality Service Research at Ryerson Polytechnic University. She is a member of the American Society for Engineering Education (ASEE), the Institute of Electrical and Electronic Engineers (IEEE) and is also a registered Professional Engineer in the Province of Ontario, Canada. Over the years, Professor Zywno volunteered her services in a variety of capacities to the engineering profession, including a Task Force on Admission (1991-93) and, since 1993, the Academic Requirements Committee (ARC) of the Professional Engineers Ontario (PEO). She is an active member of the Women in Engineering Committee and her other research interests include investigation of issues of recruitment and retention strategies for women in engineering.

Dr Judith Waalen is the Director of the Centre for Quality Service Research at Ryerson Polytechnic University in Toronto, Canada. She completed her undergraduate degree at Assumption University and earned her MA degree from the University of Windsor and her PhD from Wayne State University. Dr Waalen, whose background is in psychology as well as in evaluations and statistical analysis, has extensive teaching and research experience. Her most recent area of interest is the validation of instruments used in the measurement of attitudes and motivations, evaluation research studies and single subject research designs. Her current role at Ryerson involves working directly with faculty members to frame research projects and evaluation assessments of their pedagogy and to help them prepare their findings for public dissemination.

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