Analysis of a Learning Model Applied to an Engineering Course

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Abstract

A three phase learning model was applied to an Introduction to Digital Logic course at Vanderbilt University in the Spring of 2004. The three phases included administering pre-assessment inventories, facilitating collaborative exercises, and evaluating the learning experiences of the students. The first and final phases were applied to all students in the Introduction to Digital Logic course. The second phase was applied to selected sections of the course. In the initial phase, students in all sections of the course were administered the Index of Learning Styles Questionnaire, a Myers-Briggs Type Indicator, and a laboratory experiences survey. In the second phase of the learning model, the students in the selected sections participated in weekly learning sessions. The weekly learning sessions provided students with practice problem sets and a structured environment to collaboratively practice problems and discuss Introduction to Digital Logic concepts. The final phase of the learning model evaluated the performance of students in both environments. A statistical analysis of each phase was completed. A statistical correlation between the performance of the participants in the second phase and that of all other students was formulated. This research study examined students' learning style preferences, problem solving performance, gender, ethnicity, geographical backgrounds, confidence in performing course objectives, course performance, and overall performance.

Introduction

The Introduction to Digital Logic course serves as the first engineering course for many engineering students. During this pivotal point in a students' academic career, it is important that the students' initial exposure to engineering is learner centered, knowledge centered, assessment centered, and community centered[1]. A three phase learning model has been developed to provide a learning environment involving these learning essentials.

The Introduction to Digital Logic course is a course offered by the Department of Electrical Engineering and Computer Science. Students majoring in Electrical Engineering, Computer Engineering, and Computer Science are required to take to course. The course is four credit hours. It has a three-hour a week lecture and a three- hour a week lab.

Researchers conducting studies in engineering and science classrooms and laboratories have validated many of the techniques used in the learning model. Extensive use of a combination of lecturing, active learning exercises, collaborative learning exercises, and peer instruction is found throughout the learning model.

The longitudinal study of engineering student performance and retention performed at North Carolina State University in the Department of Chemical Engineering [2, 3, 4, 5, 6]. In the study, a cohort of students took five chemical engineering courses taught by the same instructor in five consecutive semesters. There were more than 100 students in the cohort. For this study, the focus was placed on analyzing: (i.) the success and failure in the introductory course, (ii.) rural/urban differences, (iii.) gender differences in student performance and attitudes, (iv.) instructional methods and students responses to them, and (v.) comparisons with traditionally-taught students. Dr. Richard Felder and a group of researchers concluded that there were factors in a student's background that might be significant predictors of success or failure in the course, and by extension, in the chemical engineering curriculum[2]. Supportive evidence was provided for the geographical disparities [3]. Attention is given to some of the difficulties that women face in the engineering classes with suggestions to help alleviate some of the difficulties[4]. There were observations given that suggested that experimental instructional methods were effectively implemented and were well received by the students[5]. The methods that constituted the experimental instructional approach have been shown in the study to have positive effects on students' academic performance, motivation to learn, and attitudes toward their education and toward themselves[6]. Though the research presented in this paper involved a single course, Introduction to Digital Logic, it included a combination of some of the instruments studied by Dr. Felder and others.

This research also embraced the study of students' learning performed by Dr. Eric Mazur on an introductory physics course at Harvard University. This study included more than 100 students. Prior to the study, Dr. Mazur was looking for ways to focus the students' attention on the underlying concepts without sacrificing the students' ability to solve problems[7]. The result of this search was Peer Instruction, an effective method that teaches the conceptual underpinnings in introductory physics and leads to better student performance on conventional problems[7]. The students' learning was evaluated through two diagnostic tests: the Force Concept Inventory and the Mechanics Baseline Test[7]. The post-inventory scores after using Peer Instruction were greater than the pre-inventory score without Peer Instruction[7]. The second phase of the learning model employed a Peer Instruction approach.

Methodology

A research study was conducted on an Introduction to Digital Logic course in the School of Engineering at Vanderbilt University (VUSE). This Spring 2004 study examined students' learning styles preferences, experiences in weekly learning sessions, problem solving, and technical writing skills.

Students pre-registered for one of the Introduction to Digital Logic sections. Students had no knowledge that different modalities of instruction would be presented. The process was essentially a random assignment to sections. Half of sections were assigned to the experimental group, and the remaining sections were assigned to the traditional group. The experimental sections received instruction through a combination of lecturing, active learning, collaborative learning, and peer instruction exercises. These instructional techniques were presented during the weekly learning sessions. Training workshops were provided for teaching assistants on techniques for incorporating lectures that extensively used active, collaborative, and peer instruction in them. Students in the experimental group received an invitation to attend the weekly learning session.

The learning model consists of three phases. Figure 1 provides a graphical image to the learning model. The initial phase is referred to as the Pre-Assessment phase. In this phase, the Index of Learning Styles Questionnaire, Myers-Briggs Type Inventory, and laboratory experiences survey were administered to all students. In Phase II of the learning model, attention was given to providing a knowledge transfer, learner centered, assessment, and community building environment. This environment was created during the weekly learning sessions. Grading rubrics were also developed to analyze the learning session problems and the practice problems. In the final phase, a laboratory experiences survey was distributed and grading rubrics were developed for the course homework sets and exams.

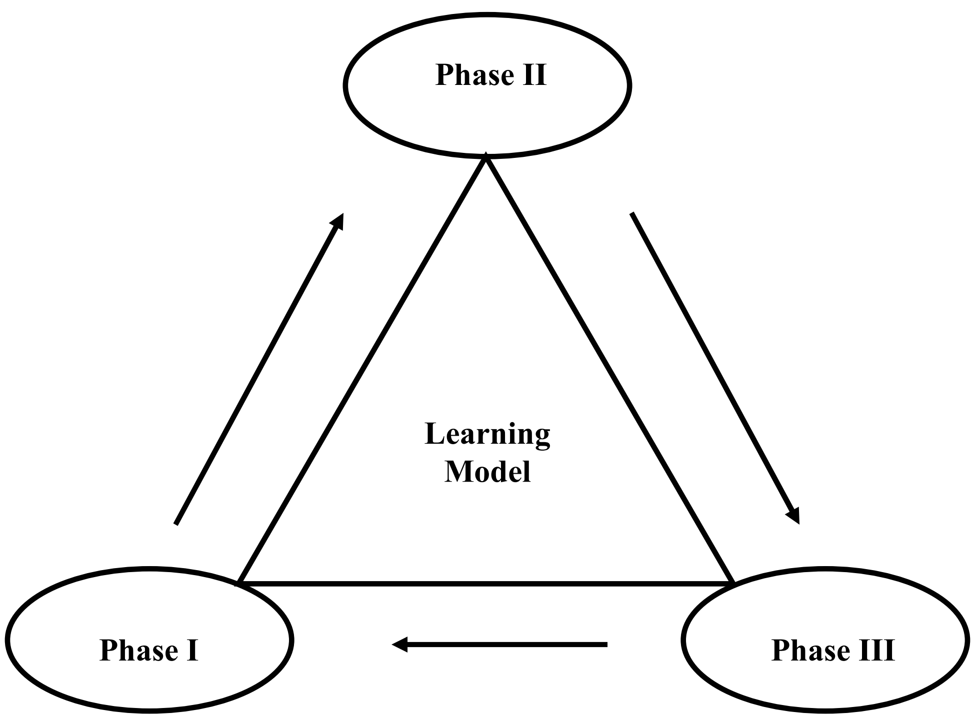

Figure 1. Diagram of Learning Model.

Students in both groups were asked to complete the online version of the Index of Learning Styles Questionnaire developed by Ms. Barbara A. Soloman of the First-Year College, North Carolina State University, Raleigh, North Carolina and Dr. Richard M. Felder, Department of Chemical Engineering, North Carolina State University North Carolina[8] and an online Myers Briggs Type Indicator[9]. Students were also asked to complete a survey about their laboratory experiences at the beginning and end of the course.

Weekly learning sessions were offered once a week for eleven weeks. These learning sessions were structured, working sessions where students had an opportunity to work problems, solidify concepts, and ask questions. These sessions provided opportunities for students to work individually and in groups. A goal of the learning session was to foster a peer instructed, collaborative learning environment where the instructor served as the coach during the sessions. Instructors for the sessions were provided techniques to manage a peer instructed, collaborative learning environment. The Peer Instruction approach developed by Dr. Mazur was used during the weekly learning[7]. The basic goals of this team-based instruction were to exploit student interaction during the weekly learning sessions and focus students' attention on underlying concepts. During the sessions, the focus was on addressing potential difficulties, deepen understanding, building confidence, and including additional examples and problems. Attending the learning sessions was optional. Students that attended at least three or more the learning sessions were considered participants of the weekly learning sessions. These students were asked to complete a survey about the weekly learning sessions.

Results

There were sixty-one students enrolled in the Introduction to Digital Logic course. All statistical analysis was process using SPSS. Table 1 provides the demographic overview of the sample. Consistent with many engineering courses, Whites and males were predominant in the sample. Though Vanderbilt University is in the South, most the students in this sample were not from the South. There were almost as many students from small towns as there were from larger cities. More than one third of the sample recorded personality types typically associated with engineers, i.e., INTJ or ISTJ. On Table 1, this is referred to as engineering type. The seven students listed as missing did not take the Myers Briggs Type Indicator.

Table 1. Demographics on Selected Variables for Original and Final Samples

		Sample	
Selected Variables	**Group**	**N**	**%**
Weekly Learning Session Participation	Yes	9	14.8
	No	52	85.2
Ethnicity	White	38	62.3
	Non-White		

		23	37.7
Gender	Female	7	11.5
	Male	54	88.5
Home Region	South	23	37.7
	Non-South	38	62.3
Size of Hometown	< 51,000	29	47.5
	≥ 51,000	32	52.5
Engineering Type	Yes	20	32.8
	No	34	55.7
	Missing	7	11.5

Table 2 shows that the sample included a higher percentage of INTJs (25.9%) than other personality types.

Table 2. Personality Type Distribution by Sample

	Final Sample	
Personality Type	**N**	**%**
ENFJ	5	9.3
ENFP	3	5.6
ENTJ	4	7.4
ENTP	0	0.0
ESFJ	2	3.7
ESFP	0	0.0
ESTJ	6	11.1
ESTP	1	1.9
INFJ	5	9.3
INFP	2	3.7
INTJ	14	25.9
INTP	1	1.9
ISFJ	2	3.7
ISFP	1	1.9
ISTJ	6	11.1
ISTP	2	3.7

Table 3 shows the sample's learning style preference by ethnicity and gender. The results from the Index of Learning Styles Questionnaire were used to tabulate the learning style preferences.

Table 3. Sample Distribution by Learning Style Preference, Ethnicity, and Gender

		Gender	
		Males	Females
Ethnicity	**Group**	**N**	
Non-White	Reflective	13	*
	Active	6	*
White	Reflective	14	3
	Active	15	3
Non-White	Sensing	10	*
	Intuitive	9	*
White	Sensing	14	4
	Intuitive	15	2
Non-White	Verbal	4	*
	Visual	15	*
White	Verbal	3	1
	Visual	26	5
Non-White	Sequential	10	*
	Global	9	*
White	Sequential	19	4
	Global	10	2

All of the non-White students in the sample were male. Reflective styles were indicated for slightly better than two thirds of the non-White students while proportions were about evenly distributed for Whites. White students demonstrated a similar percentage breakout on the Sensing/Intuitive style, but sensing was the majority style of non-White students. Visual was the predominant style over verbal for White and non-White students (88.6% and 78.9%, respectively). Likewise, sequential was the primary style, compared to global, for the majority of students, regardless of ethnicity.

A four-way analysis of variance (ANOVA) was conducted to investigate the effects of learning styles (each style = independent variable) on course grade. Course grade functioned as the measure of course performance. Table 4 shows the distribution of average course grades by learning style.

Table 4. Average Course Grade by Learning Style

Learning Style	Average Grade	Standard Deviation (Grade)
Reflective	10.13	3.47
Active	9.83	2.98
Sensing	9.36	3.30
Intuitive	10.69	3.07
Verbal	9.25	4.68
Visual	10.13	2.96
Sequential	10.00	3.20
Global	10.00	3.23

Results of the 2 x 2 x 2 x 2 (Reflective/Active x Sensing/Intuitive x Verbal/Visual x Sequential/Global) ANOVA on mean course grades indicated a significant main effect for Sensing/Intuitives. The mean course grade for Intuitives (M = 10.69, SD = 3.07) was significantly higher than the mean course grade of students with a Sensing style (M = 9.36, SD = 3.30), $F(1, 41) = 6.83$, $p = 0.012$. There were no significant two-way or three-way interactions. The grades are coded in the following manner: A+ = 14, A = 13, A- = 12, B+ = 11, B = 10, B- = 9, C+ = 8, C = 7, C- = 6, D+ = 5, D = 4, D- = 3, F+ = 2, F = 1, and F- = 0.

In addition, the impact of the class variables ethnicity and gender were analyzed. A 2 x 2 contingency table (Table 5) shows the breakdown of course grade on the two independent variables.

Table 5. Average Course Grade by Ethnicity and Gender

	Ethnicity		
Gender	***White***	***Non-White***	
Female	10.67	*	(10.67)
Male	11.21	7.95	(9.92)
	(11.11)	(7.95)	

*Empty cell

Results of the two-way ANOVA yielded a significant main effect for ethnicity, F (1, 51) = 14.50, $p < 0.001$. Whites achieved significantly higher course grades, on the average, than non-Whites (M = 11.11 and 7.95, respectively). No interaction effects were evident between ethnicity and gender.

Consistent with other studies, the research also examined the relationship between engineering type (i.e., INTJs and ISTJs) or not engineering type and the two criterion variables. Table 6 shows average course grade across levels of participation and engineering type. Mean grade point averages across the two levels of independent variables can be gleaned from Table 7.

Table 6. Average Course Grade by Participation and Engineering Type

	Engineering Type		
Participation	***Yes***	***No***	
Yes	11.50	10.40	(10.89)
No	11.50	8.90	(9.82)
	(11.50)	(9.12)	

Table 7. Mean Grade Point Average by Participation and Engineering Type

	Engineering Type		
Participation	***Yes***	***No***	
Yes	3.40	3.17	(3.28)
No	3.38	2.99	(3.13)
	(3.38)	(3.01)	

Multiple regression analysis of participation and engineering type on course grade reflected significant effects for the model, F (2, 51) = 4.12, p = 0.022. However, the model accounts for less than 15 percent of the variance in course grade (R^2 = 13.9%). Engineering type was observed to be a highly significant predictor of course grade, t = 2.71, $p < 0.01$. It could be predicted that students with INTJ or ISTJ personality types would achieve significantly higher grades in the Introduction to Digital Logic course than students manifesting other personality types. Participation was not a significant predictor of course grade. Nevertheless, students who participated in the weekly learning sessions obtained higher grades, on the average, than non-participants.

Results of multiple regression analysis of participation and engineering type on grade point average did not yield similar results. The model was not significant. In fact, the model did not approach significance ($p > 0.10$). Yet, grade point averages were higher for participants, compared to non-participants, and for students with engineering types than for students of other personality types.

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