AC 2010-2428: LEARNING BARRIERS IN SERVICE COURSES - A MIXED-METHODS STUDY

Qaiser Malik, Michigan State University

Punya Mishra, MSU

Michael Shanblatt, MSU

Learning Barriers in Service Courses: A Mixed-Methods Study

Abstract

This paper reports the results of a longitudinal study conducted on a service course offered to non-electrical engineering majors at a large Midwestern university. The study focused on understanding the reasons why students perform relatively low in service courses. The mixed method approach was used to measure the performance in two different ways and then triangulate the results for a deeper understanding of the issue. For the quantitative phase, a closed form questionnaire was developed for the entire class that measured student attitude and their understanding of core concepts related to a specific topic. For the qualitative phase, a concept map was developed for the specific topic for one-on-one interview sessions with a representative sample. The data was collected with the two instruments for five consecutive semesters ($n_1=253$, and $n_2=44$). Our analyses of the data have identified some inherent flaws in the teaching methodology for service courses that contribute towards rote learning. These courses need to be made more relevant and conceptually grounded along with a refocusing of the course content. Moreover, the two instruments developed in this study may form the basis for a broader framework for the formative evaluation of engineering courses.

Introduction

Interdisciplinary courses commonly known as service courses are offered by almost all engineering departments to meet the ABET's essential program outcomes criteria 3a-3k to prepare the future engineers for a successful and productive career^{1,2}. These courses are primarily developed by the departments for non-major engineering students with three main objectives³: 1) to prepare the students to efficiently solve the interdisciplinary problems confronted by entry level engineers in the industry⁴; 2) to adequately cover the relevant portion of the syllabus for professional certification and registration; and 3) to motivate students to learn engineering concepts related to other fields by generating enough interest in the subject^{5,6}. The past research shows that motivating the students to learn in service courses is a challenge because most students are unable to understand the link between the knowledge acquired in the service courses and their majors^{7,8}.

This longitudinal study was conducted on Electronic Instrumentation and Systems (EI&S) course, a typical service course offered by the Electrical and Computer Engineering (ECE) department of a large Midwestern university. The objective was to explore and understand the root causes of why students underperform in service courses. The research question formulated for the study was: "*What are the learning barriers for non-major engineering students in a service course?*" To seek an answer the study attempted to measure student learning in two domains of the Bloom's taxonomy: cognitive and affective⁹. For the cognitive domain a specific topic of the course was chosen to gauge student learning of the core concepts. For the affective domain, student attitude towards learning in the service course was measured. For this purpose two instruments were developed: a survey questionnaire for the entire class, and a concept map assignment on the specific topic for one-on-one interview sessions with a representative sample.

This paper reports the results for the data collected between April 2007 and April 2009 with a mixed method approach.

The Context

The field of electrical engineering (EE) has been advancing with a remarkable pace for the last three decades. The rapid advancements in EE have impacted other fields of engineering and has enhanced its importance among different engineering disciplines^{8, 10}. A host of today's cutting edge technologies crucial to the economic development of any country are the off-shoots of different branches of EE¹¹. This increased interdependence of engineering disciplines has prompted many institutions to modify their curriculums to train the future engineers to be knowledgeable in all aspects of engineering including EE. In line with these trends, the ECE department offers EI&S course, a 3 credit course for non-EE majors. The course has a large intake with approximately 100 students from mechanical, bio-system, material, applied, and civil engineering majors. The course is delivered in a traditional manner through lectures, labs, and a published e-book made available to the students via university web. The course is managed through Angel, the university's course e-management system, only to the extent of posting assignments, solutions and individual grades. The course is not assigned a fixed term faculty. Like most service courses, teaching responsibility is rotated among the departmental faculty on a 2-3 year cycle.

The course introduces the breadth of EE while providing hands-on experience in building electronic circuits using state-of-the-art test and measurement equipment. It is a compilation of a wide variety of subjects from the department's core courses that include topics in electrical components, circuits, instrumentation, frequency response, operational amplifiers, semiconductor devices and digital logic. A basic EE textbook has been specified that covers most of these topics. A three-hour per week lab session is integrated with the class lectures. Labs are designed around building practical circuits with the knowledge gained in the class. The course is designed to be highly demanding and challenging and is relatively fast paced. Based on faculty feedback and student evaluations, the general observations about the course are: 1) lack of interest by students due to non-major nature of the course; 2) low priority by department/instructors (service course syndrome); 3) fast and superficial topic coverage; 4) high student-teacher ratio; and most importantly 5) lack of a clear link between the subjects covered and the students' majors as perceived by the students.

To examine the research question the study was telescoped to a specific topic. Bipolar Junction Transistor (BJT) was selected for the research topic because it was the most complex topic of the course that required deeper understanding of basic concepts. BJT sparked the semiconductor revolution in the late 1960s and have gone on to become, in present form, ubiquitous in today's electronic equipment. Understanding transistor basics is, therefore, considered essential for all engineering majors. The course syllabus that covers the entire breadth of the EE field, allocates a mere 1.5 lecture hour to BJT. Teaching this complex topic effectively in 90 minutes had been a challenge for the instructors. Our experience show that majority of students do not perform well in this topic.

Methods

A valid and reliable instrument is essential to measure the student learning through a realistic collection of data. Two focus areas that required measurement and evaluation were: student perceptions of their understanding and student understanding of the course contents. A limited variety of *standard instruments* were available to measure student perceptions and attitudes towards learning in a general course setting¹²⁻¹⁵. A careful selection of a base line instrument helped in developing a specific instrument to meet the need for measuring student perceptions of their understandings. Measurement of understanding of the course content was a unique context that required a *content specific instrument*. Such an instrument obviously was not readily available in the literature. One has to rely on the subject specialists and education experts to develop such an instrument. More importantly, such an indigenous effort requires a number of iterative trial sequences to establish its validity and reliability before actually using it for the research. Two instruments were developed after a thorough literature search¹²⁻¹⁵ and several consultation sessions with the education experts/subject specialists: a survey questionnaire for the entire class, and a concept map for one-on-one interview sessions with a representative sample. Due to the different nature of the two instruments, one dealing with quantitative data and the other with qualitative data, the data were processed, analyzed and compiled using a mixed method approach.

The Quantitative Approach

The Class Survey: The class survey was developed with two main objectives: to measure the student attitude towards learning in the service course, and their understanding of the core concepts of the selected topic, *i.e.* BJT. It was comprised of 40 items, and was sub-divided into four sections. Three sections were developed from the available literature because they collected standard data on student attitude. Most of the 25 items in the three sections were developed on five point Likert scale with 1 and 2 representing “Strongly Disagree” and “Disagree”, 3 representing “Neutral” and 4 and 5 representing “Agree” and “Strongly Agree” respectively. The fourth section was developed by the researchers to measure student understanding of the BJT. Items in this section were in the form of simple problems that addressed the core concepts for the topic. The four sections of the instrument are briefly explained below:

- 1) **General information:** It was comprised of nine items concerning participant's background and demographics, e.g. age, class level, major, cumulative GPA, expected grade, course usefulness.
- 2) **Student perception of learning:** This section measured participants' perception of their understanding about the course, *i.e.* extent to which it met the course objectives, course pace, quality of lectures, textbook, home assignments and instructor notes. The section was comprised of ten items; two sample items are given below.

13. Lectures are monotonous, a verbal repetition of instructor notes.

16. The course material is intellectually stimulating.

- 3) **Student perception of instructional methods and use of instructional technologies:** The section included items on on-line teaching, e- management system, and multimedia and computer tools. Two of the six items in this section are given below.

38. *In my opinion use of multimedia and web technologies would have resulted in a deeper understanding of the core concepts.*

37. *ANGEL is effectively being utilized in the course delivery.*

- 4) **Student learning of course content:** This section was unique as it related to the course content. It measured the understanding of the core concepts and their relationship to the specific topic (BJT). The section was comprised of fifteen numerical problems in two distinct categories (six per category): *standard* problems and *inferential* problems. The problems in both the categories were small and simple; they did not require complicated mathematical formulas or calculator to solve them.

- a. **Standard problems:** The standard or textbook type problems were similar to the ones covered during the course in class assignments, home assignments and exams, with minor variations in numerical values and problem setup. Students were given sufficient practice on like problems. Two typical standard problems are given below:

Q#25 Find ' V_{out} ', as indicated, for the following circuit:

Note: A typical voltage-divider-network; students had sufficient practice of similar problem.

Q#30 Indicate the cut-off, active and saturation regions on the following i - v characteristic curves for a BJT:

Note: These are typical i - v characteristic curves for the BJT. Students have been using these curves to identify the three operating regions of a BJT. A similar problem was assigned in the homework.

- b. **Inferential problems:** Inferential problems required a step further to the understanding of core concepts and their interrelationship. These were the applications of the concepts discussed in class. Students had not seen such or similar problems in class, home assignments or on exams. However if the concept was understood, the student could solve these problems with ease. Two examples are shown below:

Q#22 Find the equivalent resistance for the following resistive network:

Note: This series-parallel network has a shorted link across the diagonal. The problem looks simple but requires a deeper insight of open and short circuits. Students were given these concepts and solved the problems with short and open terminals but they had not seen a similar circuit before.

Q#24 Rank and label five bulbs (A, B, C, D, E), connected in the following three circuits, from the brightest to the dimmest ('1' means the brightest, same number means same brightness). Assume all bulbs are identical, and batteries are identical ideal sources:

Note: Students were given the understanding of current divider rules in series, parallel networks. This problem is the application of these concepts and their inter-relationship. Students had not seen a similar problem before.

Data Collection: The class survey was tested for reliability and validity before it was used for data collection. The items were reviewed several times by the researchers and the department faculty for their structure, simplicity and intended meaning. It was then pilot tested on five upper level graduate students. Items were revised many times and some were rewritten based on the feedback from the faculty and the students. After obtaining approval from the Institutional Review Board, the survey was administered in five successive semesters from Spring 2007 to Spring 2009 (n=253). For simplicity, the 5-point Likert scale was collapsed into three levels, *i.e.* “Agree”, “Neutral” and “Disagree” by adding the scores on “Strongly Disagree” with “Disagree”, and “Strongly Agree” with “Agree”. Problems in Section 4 were mostly graded on a 0-5 scale with 0 meaning 0% and 5 meaning 100%.

Data Analysis and Results: The data was statistically analysed with SPSS 16.0. A summary is given below.

- 1) **Descriptive Statistics (Sections 1, 2, and 3):** Evaluation of the data revealed some interesting results.
 - a) 97% of the participants were either juniors or seniors. 66% were mechanical, 15% bio-system, 10% material, 7% applied, and 2% civil engineering majors.
 - b) 83% of the participants had good grade (CGPA > 3.0) and 80% expected to maintain their grades.
 - c) 68% of the participants devoted less than average time required for self study. Usual ratio is 1:1, *i.e.* one hour of self study per credit hour.
 - d) Only 11% considered the course easy. They were split on the issue of its usefulness (~50%).
 - e) 73% considered the course lectures monotonous while 54% perceived the course material stimulating.
 - f) 67% relied primarily on instructor notes to understand concepts. Only 22% thought consulting textbook enhanced their learning.
 - g) Though students had no exposure to online courses at the College of Engineering, 53% opined that use of multimedia and web technologies, access to additional material through online resources, and web based tools would have enhanced their understanding.
- 2) **Student Learning of Course Content (Section 4):** The data represented a sharp contrast between the understanding of *standard* and *inferential* type problems. The student scores on the four example problems in two categories are graphically represented in Figures 1 and 2. 74.1% of the students scored full marks in the two *standard* problems. The *inferential* type problems showed a very different picture; only 9.1% and 13.6% students could manage to get a perfect score.

Figure 1: Response on standard problems.

Figure 2: Response on inferential problems.

The data for twelve problems in this section further substantiated the results. On the average, 66.2% of the students scored full marks in the standard or textbook type problems (called Standard Group or Q_Std) whereas a mere 26% could manage to score full marks in the inferential type problems (called Inferential Group or Q_Inf). Paired Samples t-Test showed a significant difference between the two groups of problems (Q_Inf vs. Q_Std) with 99.9% Confidence Interval ($M = -1.63746$, $\sigma = 1.04638$, $t = -21.796$, $df = 193$, $p < .001$).

- 3) **Correlates of Success:** To identify the factors that significantly enhanced the learning of *inferential* type questions, the correlates of success, a backward stepwise linear regression model was developed in SPSS 16.0. The model was comprised of Inferential group (Q_Inf) as the dependent variable, seventeen items from Sections 1 and 2 (items 3-19) of the class survey and Standard group (Q_Std) as independent variables ($p = 0.05$ for entry and $p = .1$ for removal). Thirteenth model was finally selected. Table 1 shows the coefficients of thirteenth model in SPSS. Interpretation of the table shows that four items of the survey (Items 4, 6, 10, and 13) significantly influenced the participant learning of inferential type questions – the conceptual learning. Q_Inf and Q_Std had the strongest correlation for obvious reasons that those who did well in *standard* problems also did well in *inferential* type problems. The model defined a good student with four characteristics: 1) had high CGPA; 2) expected high grades in the course; 3) was satisfied with the course pace; and 4) considered lecture were interesting not monotonous. Such a student would significantly learn the course contents, specifically the core concepts better than the other students.

Coefficients*						
Model	Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
13	(Constant)	1.212	.385		3.145	.002
	Q_Std=(Q23/4)+(Q25/5)+(Q26/5)+(Q27/5)+(Q30/3)+(Q32/3)	.304	.042	.392	7.165	.000
	Q#4: My CGPA; below 2:00 to 4:00 (1-5)	.165	.075	.125	2.193	.029
	Q#6: My expected grade in this course ; <2.00 to 4.00 (1-6)	.107	.043	.139	2.465	.014
	Q#10: Pace of the course is fast	-.179	.065	-.135	-2.729	.007
	Q#13: Lectures monotonous, verbatim repetition of instr notes	-.137	.051	-.136	-2.703	.007

* Dependent Variable: Q_Inf=(Q22 / 5) + (Q24 / 6) + (Q28 / 5) + (Q29 / 7) + (Q31 / 6) + (Q34 / 5)
R=.572, R squared= .328, Adjusted R squared= .316

Table 1 Backward stepwise linear regression model coefficients

The results indicated that though the majority of the class was comprised of good students (Cumulative CGPA >3.00), they had negative attitude towards the course. They expected good grades but did not want to spend enough time on self study. They appeared to be focused on rote learning of textbook problems and faced difficulties when asked to apply the concepts into somewhat newer contexts. It must be emphasized that the inferential problems were not extremely difficult, nor did they need any extra knowledge on the part of the students. All that was needed was an understanding of the conceptual underpinnings of the ideas and the ability to apply them. Only those who were academically good and also had positive attitude towards the course did well in the course and learned the core concepts of the course.

A survey, such as the one implemented here, offers insight into the fact that students seemed to have problems applying the concepts they had learned. However, it is difficult using instruments such as these to identify the nature of student understanding. For this purpose we conducted a qualitative analysis of student understanding by working with a smaller representative sample of students. In this part of the study focus was not on their problem solving ability, it was on "mapping" their understanding of the relationships between key concepts. Our methodology and results of this part of the study are reported in the next section.

The Qualitative Approach

Why Concept Mapping? Concept mapping emerges directly from David P. Ausubel's assimilation theory of meaningful verbal learning¹⁶. The underlying basis of the theory is that meaningful (as opposed to rote) human learning occurs when new knowledge is consciously linked to an existing framework of prior knowledge in a non-arbitrary, substantive fashion. In rote learning, new concepts are added to the learner's framework in an arbitrary and verbatim way, producing a weak and unstable structure that quickly degenerates. The result of meaningful learning is a change in the way individuals experience the world; a conceptual change. Concept maps have been used for over 25 years in research and classroom practice to reveal and assess the structure and complexity of knowledge held by students in the sciences and other disciplines¹⁷. An important benefit of using concept mapping as an assessment method is its

ability to detect or illustrate students' deep content understandings as well as their misconceptions when they create a personal explanation of content matter¹⁸.

Expert Map for BJT: To investigate and develop an expert map for the selected topic of BJT, we formed a group of experienced faculty of the department. The group selected a set of seventeen concepts for the topic to which another three were added for redundancy. An expert version of the map was developed in Inspiration®. Inspiration® is currently among the most popular concept mapping software programs¹⁹. Several trial runs were conducted with EE faculty experts to finalize the expert map before it was put to test. The final map is shown in Figure 3.

Figure 3: Expert concept map for BJT module.

Testing and Evaluation: The concept mapping sessions were administered one-on-one to 44 randomly selected students from five achievement groups (2 students per group per semester). The groups, formed on the basis of academic performance in the course, were: Excellent (above 90%), Good (80-90%), Average (70-80%), Fair (60-70%), and Poor (less than 60%). Each session of 30-40 minutes included a briefing on the concept mapping technique and a short tutorial on the use of the Inspiration® software package. The participants were encouraged to “think aloud” as they developed the concept map so as to keep the interviewer informed about what was going on in their mind (This paper does not offer any analysis of the “think aloud” protocols). We focused primarily on the qualitative aspects of students' concept maps with emphasis on the accuracy and validity of the knowledge students presented. While comparing each participant map with the expert map we asked the following questions:

- 1) Are the most important concepts depicted?
- 2) Are the links among concepts scientifically acceptable?
- 3) Is there a substantial amount of branching hierarchy and cross-linking?
- 4) Do any of the propositions suggest that the student subscribe to significant misconceptions?

Results: The interaction with the students during the interview sessions and study of the individual concept maps brought to light some possible explanations to lower performance in *inferential* type problems. The major findings were:

- 1) **Participants often lacked deep conceptual understanding of foundational ideas:** Most of the participants in the five achievement groups missed out some basic blocks from their concept maps. An example of a participant from the Excellent group (class performance: 92%) is shown in Figure 4. The student oversimplified the map and missed out some of the foundational ideas, *e.g.*, Assumed States Method, Modelling, Resistive Network Analysis, etc. (highlighted as shaded blocks in Figure 4). The missing blocks and the interconnection pattern in the concept map signify gaps in learning.

Figure 4: A student map example: missing the foundational ideas.

- 2) **Even, in cases where concepts were considered to be interrelated, the participants did so without sound reasoning:** Figure 5 shows the map of a student participant from Average group (class performance: 78%). The student had connected everything with almost every other thing. It shows significant misconceptions of basic concepts and their interrelationship.

Figure 5: A student map example: almost everything connected to everything.

Conclusion and Future Directions

Students in undergraduate engineering programs do not perform equally well in their non-major engineering courses as they do in courses that are in their major. This study presents the assessment and evaluation of student perceptions and attitudes towards learning, and understanding of core concepts related to a specific topic. This is accomplished through the development of two instruments: a survey questionnaire for the entire class and a concept map assignment for one-on-one interview sessions with a representative sample.

The survey indicated that students emphasized rote learning or were focused on solving textbook type problems. The concept maps suggested that students lacked deep conceptual understanding of foundational ideas. Even in cases where concepts were considered to be interrelated, the participants did so without sound reasoning. This paper reports the results of the longitudinal study and is an update to the interim findings reported in earlier conferences^{20, 21}.

The study completes the initial steps of an overall project aimed at formulating a strategy for improving the teaching of service courses at the undergraduate level. The future steps will involve further collection of data and a subsequent intervention in the learning process to enhance student understanding. The intervention would require restructuring of the course content, development of online modules and making better use of e-learning tools. We plan to implement these interventions in a systematic manner to better understand student knowledge of core concepts. Additionally, the development of reliable and valid subject specific instruments *i.e.*, survey and concept map as used in this study could be used for other pedagogical studies related to engineering education.

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