Innovations in Engineering Curriculum and Teaching: A Research-Based Study

by

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Abstract

Universities have progressively improved in regards to the usage of technology in teaching-learning methodologies. Tools like videoconferences, chats and blogs, podcasting [1], webcasting and webinars [1], video streaming [2], and networked educational videos [3-5] have rapidly appeared. Research [3, 6] has shown that videos are a helpful tool to engage students with different learning styles beyond the textbook and traditional lecture. They can also increase the students' enthusiasm about the concepts presented and thereby increase information retention [6]. The focus is to engage students in intellectual work that facilitates the assimilation of knowledge in a disciplined manner that will have value beyond school.

Many students who take the introduction to engineering classes are freshmen and need help in learning engineering concepts. This study discusses the development, implementation, and evaluation of a video- and game-based instructional tool called a concept tutor. These concept tutors focus on one concept at a time, and they can be used as supplemental material to a lecture. These tutors provide additional help to students in explaining the concepts taught in class to reinforce their learning. The purpose of concept tutors is to increase the undergraduate students' enthusiasm and attention toward the concepts taught using this instructional methodology. The concept tutors will engage the students in a learning process meant to improve retention rate.

The concept tutor consists of three phases. The first phase is definition and real-world applications of the concept. The second phase includes a step-by-step presentation of the concept in a general format that explains the concept through a targeted problem. The concept tutor in this

phase is split into topic videos. The third phase consists of assessments to measure the students' understanding of the material presented. After viewing each video, the students are required to answer a set of questions that test the concepts they learned. The questions after each topic are in a format that allows the students to choose the testing environment. They can choose either a regular multiple-choice assessment or a game-based assessment.

Two concept tutors were built to introduce Simulink in MATLAB (by MathWorks) to students as a graphical programming tool for controlling a LEGO Mindstorms NXT Robot [7]. These concept tutors were developed to allow a self-paced review of Simulink GUI and programming logic concepts. The third concept tutor developed addresses the topic of units, conversions, and dimensions. This tutor is used to stress the importance of using proper units in engineering as well as reinforce the need and method of converting a physical quantity from one unit to another.

Quantitative and qualitative results show that students find such materials useful; furthermore, the students preferred this method to complement a lecture. The development methodology of the tutor and evaluation results are reported in this study.

The objective of the conventional undergraduate engineering curriculum is to equip students with the college level mathematics and basic sciences in their freshman year and then introduce core engineering courses pertaining to the students' majors [8]. Srivastava et al. [9] explain the drawbacks of the conventional engineering curriculum. According to this study, students find difficulty in engaging themselves with the materials provided. The material presented to the students is not revisited in another relevant course. For effective learning, the basic concept has to be revisited repeatedly [10], which means students have a lower knowledge retention rate. Further, the conventional curriculum does not connect one course to another as the students' progress through their program. The "spiral curriculum" revisits a concept several times and teaches more complex concepts as the students' progress through the curriculum. The spiral curriculum also integrates concepts across courses during the program [11].

Hence the spiral curriculum has to impart skills on to the students at each level of the curriculum. The term "skills" refers to the abilities the students should possess after completion of each course in spiral curriculum. These abilities are set by Accreditation Board for Engineering and Technology (ABET). This study concentrates on the skills under the cognitive domain of Bloom's taxonomy [12] namely knowledge, comprehension, application, analysis, synthesis and evaluation. Two undergraduate level ecological engineering courses, designed within a spiral curriculum, are evaluated for their role in potentially developing the required skills in the students. The courses are evaluated by comparing the students' final exam scores to the expected or ideal scores set by the instructors of those courses using the ABET criteria.

Finally a conclusion is made for each of the courses from the difference between the ideal scores and the actual scores of the students. The instructional and assessment approaches in these courses would be modified to minimize this difference.

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Chapter 1

Introduction

Most of the university professors were not taught how to teach in graduate school or when they began their first faculty position. They go on with how their professors taught, but nobody taught them about teaching either [13]. This may not help the students in achieving their learning outcomes set by the instructors. A course should be designed to engage students in the process of learning and nurture the skills that will be required to master the concepts in that course.

Objectives

The objectives of this study are to do the following:

1. Improve the students' performance, engagement, and enthusiasm towards various engineering concepts by designing and developing an innovative teaching- learning methodology, the concept tutor.
2. Evaluate two undergraduate ecological engineering courses in spiral curriculum in terms of their learning objectives.

Significance of concept tutor

Students consult resources outside the classroom materials to supplement their learning. These resources may sound useful from the students' point of view but may not actually cover the entire concept taught in the class or may include concepts that are out of scope of the course. The concept tutor developed is tailor-made to each concept, which relates to the conventional lecture. This concept tutor can be developed by the instructors for explaining any concept as they wish. Universities around the globe can make use of such a template to grab students' attention on a particular concept.

Significance of evaluation of engineering courses

The undergraduate level engineering courses mold the students' skill sets as they progress through their curriculum. The analyses performed give the instructors a way to assess their learning materials provided to the students. The analysis will help in creating a better course structure, depending on the skill set required by the students. This type of analysis on each course will help the spiral curriculum as a whole to improve the learning outcomes of the students. It will also increase the knowledge retention rate among students.

Organization of the Study

This study is divided into two major topics.

1. Design, Development and Evaluation of Concept Tutors
2. Evaluation of Courses in an Ecological Engineering Spiral Curriculum

The second chapter gives a brief literature review of new teaching-learning methodologies and course evaluation in spiral curriculum. It explains the development, implementation and evaluation of concept tutors along with the results and conclusion. This covers three concept tutors. The first two concept tutors explains the use of Simulink in programming a Lego Mindstorms NXT Robot, while the third concept tutor explains the concept of units, dimensions, and conversions. Finally future research that could make the concept tutors more effective is presented.

Third chapter is about the evaluation of ecological engineering courses in spiral curriculum. It describes the importance of different skill set students should possess with the help of Bloom's taxonomy. An in-depth analysis has been done on two undergraduate level engineering courses, which gives a suggestion on the lecture contents. It includes future work that can be done to improve ecological engineering courses with this work as the foundation.

Chapter 2

Design, Development and Evaluation of Concept Tutors

Literature Review

Research by Holtzblatt et al. has shown that videos can be used as a beneficial tool to increase student engagement and enthusiasm [6] in the learning process. This has a direct impact in increasing information retention, which will have value beyond school [14]. Media-based presentations are beneficial not only from the standpoint of reproduction of factual information but also for information processing [4]. Providing students with this kind of material gives them the opportunity to adapt the presentation to their own cognitive needs and skills.

A 2011 study concluded that online videos are the most used multimedia recourses in class and outside class [15] not only by students but also by 80% of faculty. During classes, students must face the problem of rapidly organizing the information presented at a rate that they cannot change. While reading the textbook allows them to tune their information gathering to their cognitive needs [4], video material can enhance the process by adding audio to the visual. In a 1984 article, Benjamin Bloom found that average students under tutoring perform two standard deviation better than those students that learn under conventional methods [16]. Another study [17] found that 70% of students who used videos before or after a classroom lecture said it was helpful to understand the class material. Sharing of educational videos in existing educational platforms is of high value of interest and registered increase in student motivation [2].

Two separate groups of college students at a large southeastern university have conducted surveys regarding the need for a specialized online tutoring. The survey results show that a majority of the students who use search engines to seek help for homework benefitted from online tutoring that targeted specific class material. Students listed YouTube, DVDs, Khan Academy, tutoring study guides from bookstores, and chegg.com as some of the materials that helped them outside class. While 74% said this form of supplemental material helped improve their overall learning experience, the students disliked that this material didn't have step-by-step instructions. However, they liked being able to watch the video as many times needed and said it allowed for multiple ways of learning the same thing. Furthermore, 83% said they felt that a voice-animated lecture, followed by practice problems, would be helpful with learning school material. The survey participants also suggested that in a supplemental material there should be "voice over games," "easy-to-understand practice material," "ease of use and access to variety of material," or "professor's own form of supplemental material." The responses from the surveys show that because in-class information requires fast organization and processing of information, students search for supplemental materials to satisfy their learning styles.

One such supplemental material is Khan Academy, an instructional website that has 7-minute to 14-minute videos with a voice over by Mr. Salman Khan, founder of Khan Academy, presenting a concept or how to solve a problem. The images in the video are hand-scribed formulas, diagrams, and key words that appear on the screen aligned with the audio explanation [5]. Khan Academy videos do not go very deep into the subjects discussed and are mostly explained through examples [18]. The videos do not target a specific audience; therefore, the content is either too advanced or too simple and fails to achieve any consistent content objectives.

This chapter outlines the development, implementation, and evaluation of an application that aims to meet the students' needs to extend student comprehension of more in-depth material presented in class.

Purpose of this Study

The purpose of this innovative teaching and learning methodology is to increase the undergraduate students' enthusiasm and attention toward the concepts taught in this method. The concept tutors will engage the students' in learning process that would have a very high knowledge retention rate.

Research Questions

1. What are the factors that occur before the start of learning process and still affect the learning outcomes?
2. Does the concept tutor address all these factors?
3. Does the concept tutor increase the students' engagement and enthusiasm toward the concepts taught through this method?

Development of Concept Tutor

The concept tutor was developed in three phases: First phase is definition and real-world applications of the concept. Second phase includes a step-by-step implementation in a general format and through a targeted problem. The instructional material is split into topic videos. The third phase consists of assessments. After viewing each video the students are required to answer a set of questions to provide them an assessment of the effectiveness of the material in enhancing the learning of the concept. The questions after each topic are in a format that allows the students to choose the environment of the testing. They can choose either a regular multiple-choice assessment or a game based assessment.

The application described in this chapter comes as a tutor with step-by-step instruction and practice problems, with game attached, after each step and at the end. The tutor-like material is created as learner-centered, in that the learners go through the material at their own pace, are actively engaged by adapting the presentation to their needs [4], and are quizzed on material after each step. Having the possibility to pause and rewind, review a video, take notes, and answer review questions, each viewer customizes his learning [3, 13]. The users are not forced to rapidly organize information because it is presented at a rate that they can control [4], thus distributing their attention and cognitive resources across the whole process of mastering a concept according to their metacognitive strategies [14]. The tutor is created so that the viewer gains a thorough understanding of theoretical concepts supplemented with numerical examples.

The concept tutor is created for two assignments in the introduction to engineering course. In the first assignment the students had to program a NXT Mindstorms Robot using Simulink in MATLAB (by MathWorks) [7] to go in a square, to avoid an obstacle and to turn the robot toward a beam of light. Approximately 93% of the students didn’t have prior experience using Simulink. Two separate tutors were developed to help students with their assignment. The second assignment involves understanding the importance of units, dimensions and conversions in engineering. Though the concepts of units, dimensions, and conversions are introduced in high school, students find it difficult to apply it in the engineering field. One tutor was developed to help students in this task. This product has been created in collaboration with Toolwire Inc. Figure 1 shows the tutor user flow experience on which each concept tutor is created.

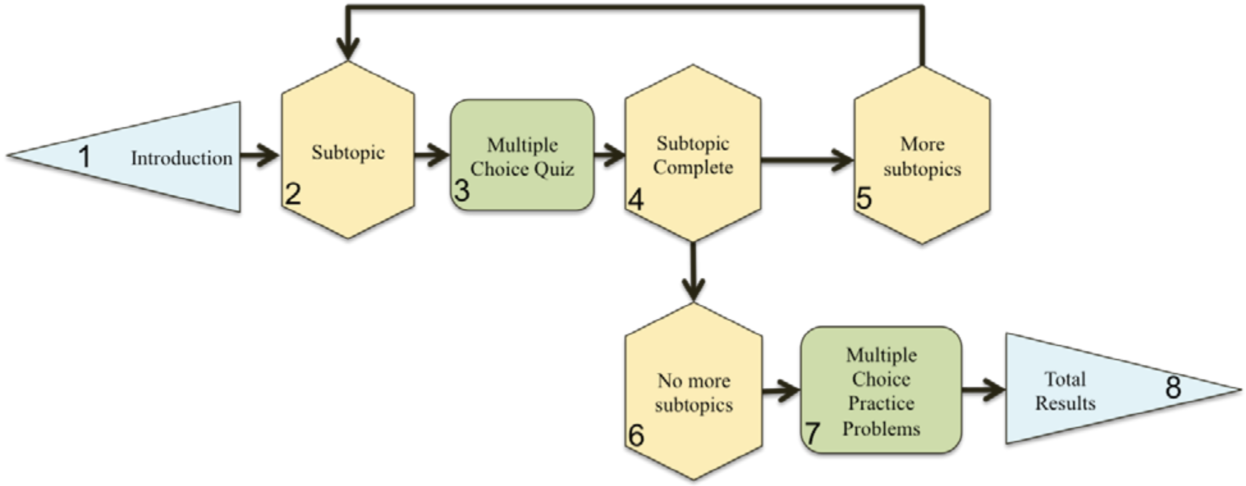

Figure 1: Tutor User Flow Experience

Before the user starts the learning process, the viewer has to choose the type of game he wants to play while self-assessing his learning. There are three options. In the first option, no game, students answer the multiple-choice questions after each subtopic and at the end (blocks 3 and 7 in Figure 1) without playing a game. The second option is a medium difficulty game. In this case, the learner will gain points by connecting correct answers in a grid. There are no points deducted if the answer is incorrect. The third option for playing a game involves moving toward the correct answer while avoiding enemies. After the game option is selected, the tutor starts with an

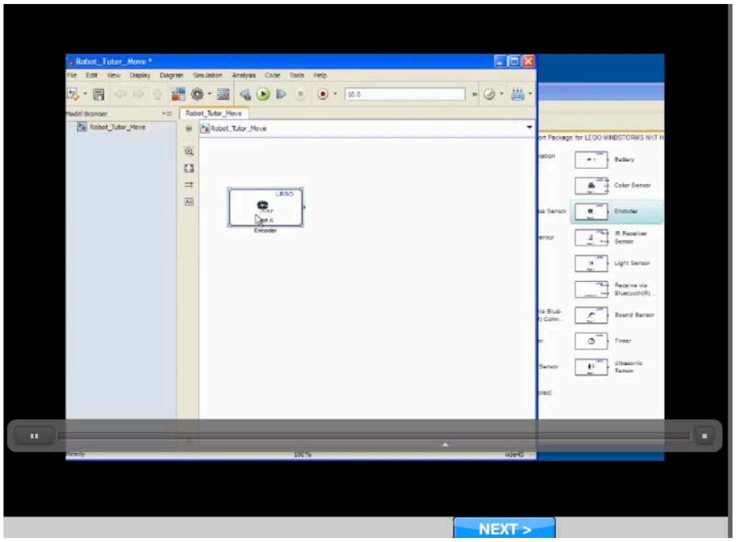

Figure 2: Tutor video for one step in the application

introduction (as in first block in Figure 1) to the topic to be discussed. This section includes objectives of the tutor, a short description of the concept, and real-world applications.

In terms of intellectual quality, the tutor has to maintain clear purpose and focus throughout and also needs to have a compelling application of the concept. Block 2 in Figure 1 represents each step that the overall concept is divided into, subtopics. Each subtopic consists of a video describing the step (Figure 2) followed by a small number of self-assessment questions from the same step.

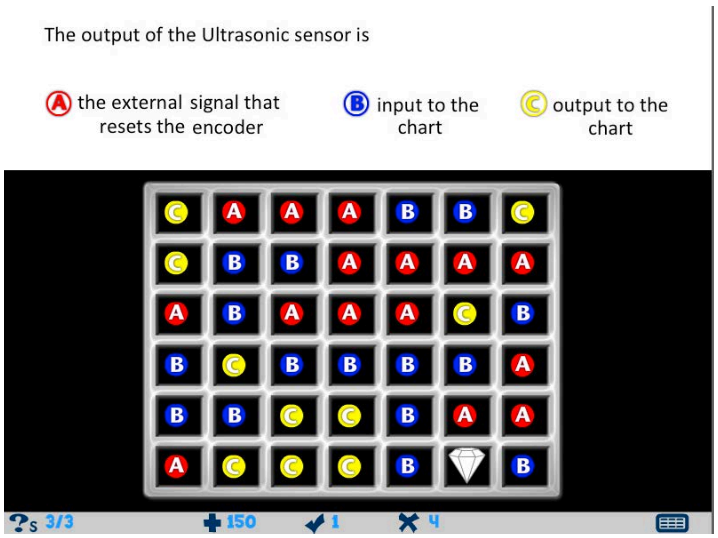

Figure 3: Screenshot of a self-assessment question

This part can be of multiple subtopics according to the number of steps needed to complete the definition or methods employed. After each step, the viewer has to answer a series of questions for the respective step for in-depth retention and self-assessment (Figure 3). After the last subtopic is completed, a set of 10-15 questions is provided from the entire material. The aim of this sequential composition is to maintain a progressive learning [13] approach that can be adapted to all learning styles.

Implementation of Concept Tutor

Two concept tutors were created and tested in an introduction to engineering course with freshman students at Auburn University. The objective of the study was to evaluate the capability of instructional video and game based teaching methodology to reinforce learning of engineering concepts. There are two learning modules used in each assignment (Simulink and Units). The first module is called the Simulink (or Units) Learning Module 1 (SLM 1). In this module the students are exposed to a lecture on Simulink (or Units). The second module is called the Simulink (or Units) Learning Module 2 (SLM 2). In this module the students are exposed to the same lecture on Simulink (or Units) and the tutor applications. In the lecture the instructor used a PowerPoint presentation to teach the use of Simulink in programming a NXT Robot (or the importance of units, dimensions, and conversions). In terms of training, students watched an instructor go through a practice test (Figure 1, block 3 alone) to demonstrate the way the three game options work. The purpose of the practice test was to get the testers familiarized with the environment and to explain the game interface. After the practice was finished, each student was directed toward a computer and was given access to the activity. At this point the students were free to manipulate the application at their own pace. At the completion of the exercise, the students were asked to fill a survey that included open-ended questions. The survey questions were strictly regarding quality of the video to enhance the tutor. In this way each concept tutor is created with the students to meet their expectations.

The targeted student groups for this experiment were 118 freshman engineering students at Auburn University. An experimental and control section were used to obtain students' perception on the capabilities they achieved while performing these learning modules. There were three experimental and three control sections. The instructional material covered in the control and experimental sections is explained below.

The control section performed Simulink (or Units) Learning Module 1 (SLM 1), which covered the following instructional material consists of Lecture on Simulink (or Units). The control section had 57 students in SLM 1 and 60 students in Units Learning Module 1 (ULM 1).

The experimental section performed Simulink (or Units) Learning Module 2 (SLM 2), which covered the instructional material, Lecture on Simulink (or Units), and video- and game-based concept tutors on Simulink (or Units). The experimental section had 60 students in SLM 2 and 57 students in ULM 2.

Evaluation Model

The video- and game-based concept tutors affects the higher order cognitive skills (HOCS), concentration, and goal clarity of the students. The effects of gender and race are found. Personal factors / characteristics do have an effect on a students' attitudes toward learning and learning outcomes (Biggs 1970, 1987, 1992, Dart et al., 2000) [15-18]. By studying the attitude toward learning models used by Biggs and Moore's (1987) [16] and Nemanich et al., (2009) [19], 4P model was developed by Sankar et al. (2010) [20]. According to this model the student's attitude toward learning (process factors) is affected by presage conditions and learning modules (pedagogy factor). The process factors in turn affect the learning outcomes (product factors). The students' learning outcomes in Simulink (or Units) concept depend on presage and process factors. Figure 1 shows the 4P model with learning modules being the moderating variable.

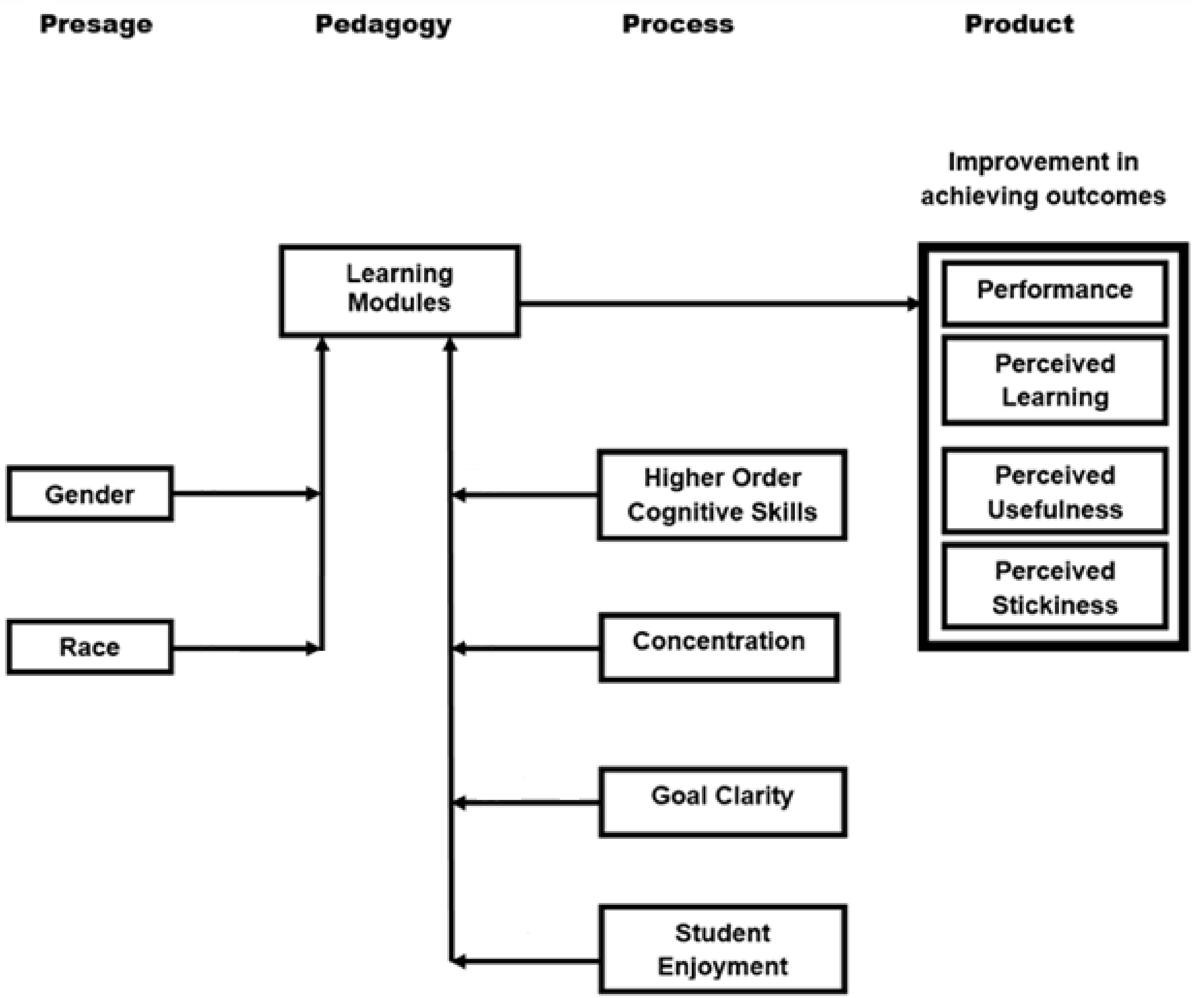

Figure 4. 4P model with learning modules as the moderating variable

Presage

Presage factors are those that occur before the start of learning process and still affect the learning outcomes. The presage factors affect the process factors as well by interacting with learning module. Gender and race are counted as presage factors. These factors are independent variables in this model.

Pedagogy

As mentioned before, the control section performed Simulink (or Units) Learning Module 1 (SLM 1). The experimental section performed Simulink (or Units) Learning Module 2 (SLM 2).

Process

Process is the learning modules or the instructional tools given to the students that might or might not give rise to desired learning outcomes (Biggs et al., 2001) [21]. The students' learning experience is incorporated in Process. (Nemanich et al., 2009)[19]

Higher Order Cognitive Skills (HOCS)

Skills such as analysis, evaluation, and synthesis are considered as higher-order cognitive skills in Bloom's Taxonomy. The ABET (2009) [22] 3(e) criterion states that students need to be able to identify, formulate, and solve engineering problems at the end of their education. The questions measuring higher-order cognitive skills are taken from Hingorani et al. (1998) [23]. These questions are shown in Table 1.

Concentration (CONC)

Concentration is thinking and analyzing the same task over a period of time without losing attention. In order to secure the students' concentration, only a targeted scope of information should be allowed into awareness (Csikszentmihalyi, 1990) [24]. The tutor with the game is designed to minimize the distraction of the students. The questions measuring concentration are taken from Koufaris (2002) [25]. These questions are shown in Table 1.

Goal Clarity (GC)

Many students fail to achieve their goals because they do not have a clear vision of their goal. This refers to goal clarity. This helps the students to focus on the things that will lead them toward their goal. The questions measuring goal clarity are taken from Guo et al., (2009) [26]. These questions are shown in Table 1.

Student Enjoyment (SE)

This refers to the pleasure the students attain while going over the learning modules. Typically it could be referred to the students desire to complete the instructional tools. The questions measuring student enjoyment are taken from Nemanich at al., (2009) [19]. These questions are shown in Table 1.

Product

Product factors are those that students have gained by participating in the learning modules. They are the outcome of the instructional tools. Three product factors are identified and these are explained below.

Performance

There are two measures of performance

Simulink Tutor	**Units Tutor**
1 The students were given two assignments on programming a LEGO NXT robot using Simulink. The score is the average of these two assignments. This will be referred to as Robot Lab Assignment Score (RLAS) in rest of the study	The final exam score of the Units, Dimensions and Conversions questions.
2 quizzes after the learning modules. The performance score is the average of the two quizzes. This will be referred to as Robot Lab Quiz Score (RLQS) in the rest of the study	Students took a quiz after the learning module. The performance score is the score on this quiz. This will be referred to as Units Quiz Score (UQS) in the rest of the study

Perceived Subject Matter Learning (PSML)

Perceived subject matter learning is the awareness and the approach toward the subject matter. This may be affected by different learning modules. The questions measuring perceived subject matter learning are taken from Alavi et al. (2002) [27]. These questions are shown in Table 1.

Perceived Usefulness (PU)

This refers to the belief students have on the learning modules that it would increase their knowledge. The questions measuring perceived usefulness are taken from Malhotra et al. (2003) [28] and are shown in Table 1.

Perceived Stickiness (PS)

The students may like the learning module and may revisit again and again to gain knowledge. Stickiness was described by Wu, Wang, and Tsai (2009) [29] with the help of online games. According to them the stickiness is the inclination of the gamers toward the online game. The questions measuring perceived stickiness are taken from Lin (2007) [30] and are shown in Table 1.

Table 1. Perceived and demonstrated measures of process and product variables

Constructs/ Items	**Measures**
Process Variables *1. Higher order cognitive skills*	***Perceived*** *measures of higher order cognitive skills used by Hingorani et al., (1998)*

	• *The instructional materials in the Simulink (or Units) learning module helped me identify engineering tools that will assist me in decision-making.* • *In this Simulink (or Units) learning module I learned how to inter-relate important topics and ideas using the instructional materials.* • *In this Simulink (or Units) learning module I learned how to identify various alternatives/solutions to a problem using the instructional materials* • *The instructional materials in this Simulink (or Units) learning module improved my problem solving skills* • *I learned how to sort relevant from irrelevant facts using the instructional materials in this Simulink (or Units) learning module.*
2. Concentration	***Perceived*** *measures of concentration used by Koufaris (2002)* • *I was absorbed intensely in the Simulink (or Units) learning module.* • *My attention was focused on the Simulink (or Units) learning module.* • *I concentrated fully on the Simulink (or Units) learning module* • *I was deeply engrossed in the Simulink (or Units) learning module*
3. Goal Clarity	***Perceived*** *measures of goal clarity used by Guo & Klien (2009)* • *I knew clearly what I wanted to do in the Simulink (or Units) learning module.* • *I had a strong sense of what I wanted to do in the Simulink (or Units) learning module.*

	• *I know what I wanted to achieve in the Simulink (or Units) learning module.* • *My goals were clearly defined in the Simulink (or Units) learning module.*
4. Student Enjoyment	***<u>Perceived</u>*** *measures of student enjoyment used by Nemanich et al (2009)* • *The learning module has been enjoyable* • *This was one of my favorite learning modules* • *I had fun working on this learning module* • *I enjoyed many aspects of this learning module*
Product Variables *1.Performance*	***<u>Demonstrated</u>*** *measures of performance* • *Robot Lab 1 & 2 Scores* • *Robot Quiz & Units Quiz Score* • *Final exam score in Units*

2. Perceived Subject Matter Learning	***Perceived*** *measures of perceived subject matter learning used by Alavi et al.,(2002)* • *I became more interested in the concept of Simulink (or Units)* • *I gained a good understanding of the concept of Simulink (or Units)* • *I developed the ability to communicate clearly about the concept of Simulink (or Units)* • *I was stimulated to do additional work in the area of "Simulink (or Units)* • *I found the Simulink (or Units) learning module to be a good learning experience*
3. Perceived Usefulness	***Perceived*** *measures of usefulness used by Malhotra and Galletta, 2003* • *Using the Simulink (or Units) learning module improved my performance* • *Using the Simulink (or Units) learning module enabled me to accomplish my tasks more quickly* • *I found the Simulink (or Units) learning module useful* • *Using the Simulink (or Units) learning module increased my productivity* • *Using the Simulink (or Units) learning module enhanced my effectiveness* *Using the learning module made it easier to do my work*

4. Perceived Stickiness	***Perceived*** *measures of stickiness used by Lin(2007)* • *I would stay longer on this learning module than others* • *I intend to prolong my staying on this learning module* • *I would visit this learning module as often as I can* • *I intend to link to this learning module when I am studying concepts that involve using Simulink to program a robot*

Evaluation Results:

Quantitative

In order to test the relationships in Figure 4, independent t-tests (i.e., mean comparisons) were performed. The data in the following tables represent the results of the mean comparisons for several variables of interest across the control and experimental groups. P-values that were significant at the .05 level or smaller are highlighted (bold and italics) and reported. Further explanation is given for each of the significant results.

Simulink Tutor Evaluation

Table 2. Mean comparisons among several outcome variables of interest for the Simulink tutor

Variables		M	SD	N	t	df	p
Higher Order Cognitive Skills	Control	2.82	0.933	57	2.640	115	***.009*****
	Experimental	3.25	0.809	60			
Concentration	Control	2.91	0.885	57	2.633	115	***.010*****

	Experimental	3.31	0.758	60			
Student Enjoyment	Control	2.68	1.050	57	2.274	115	***.025****
	Experimental	3.10	0.969	60			
Goal Clarity	Control	3.19	0.944	57	1.345	115	.181
	Experimental	3.41	0.821	60			
Perceived Subject Matter Learning	Control	2.83	0.976	57	1.983	115	***.050****
	Experimental	3.16	0.817	60			
Perceived Usefulness	Control	2.71	0.910	57	2.988	115	***.003*****
	Experimental	3.22	0.938	60			
Perceived Stickiness	Control	2.63	0.873	57	2.189	115	***.031****
	Experimental	2.97	0.833	60			
Robot Lab Quiz Score (Max 10)	Control	5.75	1.313	57	8.800	115	***.000******
	Experimental	7.88	1.303	60			
Robot Lab Assignments Score (Max 100)	Control	60.59	24.337	57	8.866	89	***.000******
	Experimental	93.37	14.026	60			

Note. *p<.05, **p<.01, ***p<.001

Several significant findings were revealed in the Table 2. All the student scores on perception measures (higher order cognitive skills, concentration, student enjoyment, perceived subject matter learning, perceived usefulness, and perceived stickiness) and objective measures (robot quiz and lab assignments scores) were significantly different between the control and the experimental groups, in that the experimental group displayed higher scores. This suggests that the students in the experimental group had improved their higher-order cognitive skills, concentration, student enjoyment, subject matter learning, usefulness and stickiness while using the Simulink tutor and also they had higher scores on the robot lab quiz and assignment than the control group. To understand which gender and race subgroups made a significant difference, further analyses was conducted and the results are shown in Tables 3 - 10.

Table 3. Mean comparisons of Higher Order Cognitive Skills (HOCS) for Gender and Race for Simulink tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males HOCS				2.398	99	***.018****
Control	2.80	0.952	53			
Experimental	3.22	0.775	48			
Females HOCS				0.572	14	.577
Control	3.05	0.681	4			
Experimental	3.35	0.961	12			
Minority HOCS				1.180	10	.265
Control	3.12	0.778	10			
Experimental	3.80	0.283	2			
Caucasian HOCS				2.716	103	***.008*****
Control	2.76	0.958	47			

Experimental	3.23	0.815	58			

*Note. *p<.05, **p<.01, ***p<.001*

After finding that the overall mean higher order cognitive skills scores of control and experimental groups were significantly different (p = .009), additional analyses was conducted to find the relevant subgroups. The results of Table 3 revealed two significant findings between mean scores. The perceived gain in higher order cognitive skills of males and Caucasians were significantly different between the control and experimental groups. Specifically, males in the control group (μ=2.80) had significantly lower scores than males in the experimental group (μ=3.22), (p=.018). In the Caucasian subgroup, it was observed that Caucasians in the control group (μ=2.76) had significantly lower scores than Caucasians in the experimental group (μ=3.23), (p=.008)

Table 4. Mean Comparisons of Robot Lab Assignment Score (RLAS) for Gender and Race

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males RLAS				8.275	86.043	***.000****
Control	59.70	24.633	53			
Experimental	92.72	14.654	48			
Females RLAS				3.1	14	***.008***
Control	72.37	18.420	4			
Experimental	95.96	11.330	12			
Minority RLAS				3.991	9	***.003***
Control	59.65	33.558	10			
Experimental	102.00	0.000	2			

Caucasian RLAS				8.593	74.440	***.000****
Control	60.79	22.372	47			
Experimental	93.07	14.175	58			

*Note. *p<.05, **p<.01, ***p<.001*

Four significant results were observed in the Table 4. The Robot Lab Assignment Scores (RLAS) of the males, females, minorities, and Caucasians were significantly different between control and experimental groups. Specifically, males (μ=59.70), females (μ=72.37), minorities (μ=59.65), and Caucasians (μ=60.79) in the control group had significantly lower robot lab assignment scores compared to the males (μ=92.72), females (μ=95.96), minorities (μ=102.00), and Caucasians (μ=93.07) in the experimental group respectively (p=.000(male), p = .008(female), p=.003(minority), p=.000(Caucasian)).

These results can be interpreted to suggest that all the students who responded positively to the Simulink tutor did well on the robot lab assignments.

Table 5. Mean Comparisons of Robot Lab Quiz Score (RLQS) for Gender and Race

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males RLQS				8.198	99	***.000****
Control	5.68	1.312	53			
Experimental	7.85	1.353	48			
Females RLQS				1.979	14	.068
Control	6.75	0.957	4			
Experimental	8.00	1.128	12			
Minority RLQS				3.536	10	***.005****
Control	6.00	1.155	10			

Experimental	9.00	0.000	2			
Caucasian RLQS				8.226	103	***.000****
Control	5.70	1.350	47			
Experimental	7.84	1.309	58			

Note. **p<.05, **p<.01, ***p<.001*

The results in the Table 5 reveal three significant results. The Robot Lab Quiz Scores (RLQS) of males, minorities, and Caucasians were significantly different between control and experimental groups. Specifically the mean quiz scores of males (μ=5.68), minorities (μ=6.00), and Caucasians (μ=5.70) in the control section are significantly lower compared to the mean quiz scores of all males (μ=7.85), minorities (μ=9.00), and Caucasians (μ=7.84) in the experimental group respectively (p=.000(male, p=.005(minority), p=.000(Caucasian)).

These results suggest that males, minorities, and Caucasians responded positively to the Simulink tutor with regard to the Robot Lab Quiz Scores. Further research should be conducted to validate these results and determine the existence of relationships between the robot lab assignment and quiz scores and other constructs of interest that may contribute to student retention and success in the STEM disciplines.

Table 6. Mean Comparison of Concentration for Gender and Race for Simulink tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males Concentration				2.407	99	***.018****
Control	2.90	0.907	53			
Experimental	3.29	0.696	48			
Females Concentration				0.624	14	.543

Control	3.06	0.554	4			
Experimental	3.39	1.002	12			
Minority Concentration				0.200	10	.845
Control	3.15	0.637	10			
Experimental	3.25	0.707	2			
Caucasian Concentration				2.750	103	***.007****
Control	2.86	0.926	47			
Experimental	3.31	0.766	58			

*Note. *p<.05, **p<.01, ***p<.001*

Two significant results were observed in Table 6. After finding that the overall mean perceived concentration scores of the control (μ=2.91) and experimental (μ=3.31) groups were significantly different, (*p*=.010), additional analyses was conducted and found that the relevant subgroups were males and Caucasians. Specifically, males in the control group (μ=2.90) had significantly lower scores than males in the experimental group (μ=3.29), (*p*=.018). In the Caucasian subgroup, it was observed that Caucasians in the control group (μ=2.86) had significantly lower scores than Caucasians in the experimental group (μ=3.31), (*p*=.007).

These results could be interpreted to suggest that males and Caucasians responded positively to the Simulink tutor with regard to their perceived concentration.

Table 7. Mean Comparisons of Student Enjoyment (SE) for Gender and Race

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males SE				2.178	99	***.032****

Control	2.65	1.069	53			
Experimental	3.09	0.912	48			
Females SE				0.315	14	.757
Control	2.94	0.826	4			
Experimental	3.14	1.217	12			
Minority SE				-0.601	10	.561
Control	3.45	0.904	10			
Experimental	3.00	1.414	2			
Caucasian SE				3.058	103	***.003*****
Control	2.51	1.012	47			
Experimental	3.10	0.968	58			

Note. **p<.05, **p<.01, ***p<.001*

Two significant results are revealed in Table 7. After finding that the overall mean perceived student enjoyment scores of the control (μ=2.68) and experimental (μ=3.10) groups were significantly different, (*p*=.025), additional analyses was performed and found that the relevant subgroups were males and Caucasians. Specifically, males in the control group (μ=2.65) had significantly lower scores than males in the experimental group (μ=3.09), (*p*=.032). In the Caucasian subgroup, it was observed that Caucasians in the control group (μ=2.51) had significantly lower scores than Caucasians in the experimental group (μ=3.10), (*p*=.003).

Table 8. Mean Comparisons of Perceived Subject Matter Learning (PSML) for Gender and Race for Simulink tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males PSML				1.856	96.95	.066

Control	2.82	1.003	53			
Experimental	3.16	0.783	48			
Females PSML				0.555	14	.588
Control	2.87	0.595	4			
Experimental	3.17	0.979	12			
Minority PSML				-0.046	10	.964
Control	3.27	0.702	10			
Experimental	3.25	0.707	2			
Caucasian PSML				2.356	103	***.020****
Control	2.73	1.006	47			
Experimental	3.15	0.826	58			

Note. **p<.05, **p<.01, ***p<.001*

The results in Table 8 revealed only one significant difference between mean scores. Specifically, the gain in perceived subject matter learning of Caucasians was significantly different between the control (μ=2.73) and the experimental (μ=3.15) groups, such that the experimental group displayed higher scores (p=.020).

Table 9. Mean Comparisons of Perceived Usefulness (PU) for Gender and Race for Simulink tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males PU				2.743	99	***.007*****
Control	2.71	0.926	53			
Experimental	3.22	0.916	48			

Females PU				0.943	14	.362
Control	2.70	0.774	4			
Experimental	3.25	1.065	12			
Minority PU				-0.240	10	.815
Control	3.32	0.620	10			
Experimental	3.20	0.848	2			
Caucasian PU				3.501	103	***.001*****
Control	2.58	0.914	47			
Experimental	3.22	0.948	58			

*Note. *p<.05, **p<.01, ***p<.001*

The result of Table 9 revealed two significant findings. After finding that the overall mean perceived usefulness scores of control and experimental groups were significantly different (p = .003), additional analyses was conducted and found that the relevant subgroups were males and Caucasians. Specifically, males in the control group (μ = 2.71) had significantly lower scores than males in the experimental group (μ = 3.22), (p =.007). In the Caucasian subgroup, it was observed that Caucasians in the control group (μ = 2.58) had significantly lower scores than Caucasians in the experimental group (μ = 3.22), (p = .001)

Table 10. Mean Comparisons of Perceived Stickiness (PS) for Gender and Race for Simulink tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males PS				1.992	99	***.049****
Control	2.63	0.902	53			

Experimental	2.97	0.786	48			
Females PS				0.803	14	.435
Control	2.55	0.341	4			
Experimental	2.98	1.039	12			
Minority PS				-0.337	10	.743
Control	3.18	0.670	10			
Experimental	3.00	0.848	2			
Caucasian PS				2.755	103	***.007*** **
Control	2.51	0.872	47			
Experimental	2.97	0.839	58			

*Note. *p<.05, **p<.01, ***p<.001*

Two significant findings were revealed in Table 10. After finding that the overall mean perceived stickiness scores of control and experimental groups were significantly different (p = .031), additional analyses was conducted and found that the relevant subgroups were males and Caucasians. Specifically, males in the control group (μ = 2.63) had significantly lower scores than males in the experimental group (μ = 2.97), (p =.049). In the Caucasian subgroup, it was observed that Caucasians in the control group (μ = 2.51) had significantly lower scores than Caucasians in the experimental group (μ = 2.97), (p = .007)

Summary and Findings from Simulink Tutor Evaluation

Table 11 summarizes the results of all the independent t-tests done for Simulink tutor evaluation.

Table 11. Summary of results of Tables 2-10

Table #	**Summary of results**

Table 2	• Experimental group displayed significantly higher scores on Higher Order Cognitive Skills (HOCS), Concentration (CONC), Student Enjoyment (SE), Perceived Subject Matter Learning (PSML), Perceived Usefulness (PU), and Perceived Stickiness (PS) than the control group • Robot Lab Assignment Scores (RLAS) and Robot Lab Quiz Scores (RLQS) of the experimental group > control group scores
Table 3	• Experimental group male HOCS score > control group male HOCS score • Experimental group Caucasian HOCS score > control group Caucasian HOCS score
Table 4	• Experimental group male RLAS > Control group male RLAS • Experimental group female RLAS > Control group female RLAS • Experimental group minority RLAS > Control group minority RLAS • Experimental group Caucasian RLAS > Control group Caucasian RLAS
Table 5	• Experimental group male RLQS > Control group male RLQS • Experimental group minority RLQS > Control group minority RLQS • Experimental group Caucasian RLQS > Control group Caucasian RLQS
Table 6	• Experimental group male CONC score > Control group male CONC score • Experimental group Caucasian CONC score > Control group Caucasian CONC score
Table 7	• Experimental group male SE score > Control group male SE score • Experimental group Caucasian SE score > Control group Caucasian SE score

Table 8	• Experimental group Caucasian PSML score > Control group Caucasian PSML score
Table 9	• Experimental group male PU score > Control group male PU score • Experimental group Caucasian PU score > Control group Caucasian PU score
Table 10	• Experimental group male PS score > Control group male PS score • Experimental group Caucasian PS score > Control group Caucasian PS score

> means significantly higher than

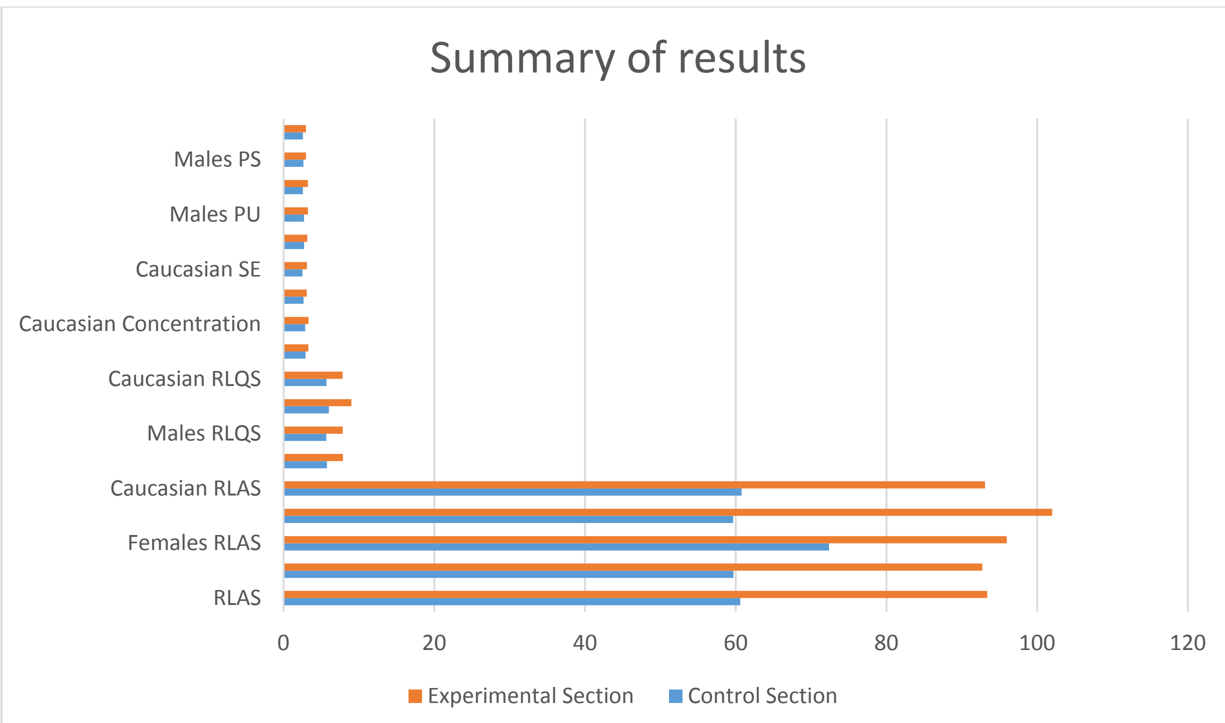

Figure 5. Table 11 in Graphical Form

The students were asked to complete a survey which included questions relating to the students' prior knowledge in computer programming. Based on this survey result, the scores of students with prior knowledge of programming were removed from the sample. This was done to remove the possible bias in the previous analysis. An independent t-test, similar to the one discussed earlier, was performed and the results are shown in table 12.

Table 12. Mean comparisons among several outcome variables without the scores of students with prior programming knowledge

Variables		M	SD	N	t	df	p
Higher Order Cognitive Skills	Control	2.926	0.9299	46	-2.026	89	***0.046****
	Experimental	3.276	0.6958	45			
Concentration	Control	2.75	0.95888	46	-2.434	89	***0.017****
	Experimental	3.1833	0.71985	45			
Student Enjoyment	Control	2.75	0.95598	46	-2.727	89	***0.026****
	Experimental	3.1833	0.8601	45			
Goal Clarity	Control	3.1793	0.88923	46	-1.92	89	0.058
	Experimental	3.5222	0.81153	45			
Perceived Subject Matter Learning	Control	2.9022	0.90443	46	-2.241	89	***0.028****
	Experimental	3.2889	0.73073	45			
Perceived Usefulness	Control	2.93	0.944	46	-1.72	89	0.089
	Experimental	3.231	0.7032	45			
	Control	2.713	0.8881	46	-1.59	89	0.115

Perceived Stickiness	Experimental	2.991	0.7722	45			
Robot Lab Quiz Score (Max 10)	Control	6.804	1.6141	46	-4.891	89	***.000****
	Experimental	8.289	1.2545	45			
Robot Lab Assignments Score (Max 100)	Control	47.2826	6.55926	46	9.028	89	***.000****
	Experimental	28.8056	12.19502	45			

Table 12 shows several significant findings. The students' scores in the experimental section on perception measures (higher order cognitive skills, concentration, student enjoyment and perceived subject matter learning) and objective measures (robot quiz and lab assignments scores) were significantly higher than the control section. This suggests that the students in the experimental group had improved their higher-order cognitive skills, concentration, student enjoyment and subject matter learning while using the Simulink tutor and also they had higher scores on the robot lab quiz and assignment than the control section.

Several significant differences during the data analysis for the 4P model was found, and several non-significant mean comparisons was observed. In total, several meaningful observations are made that can potentially provide guidance for instructors trying to improve their instructional materials and researchers seeking to conduct experiments involving comparison of multiple instructional materials.

Beginning with Table 2, higher perceived gains was observed in higher order cognitive skills, concentration, student enjoyment, subject matter learning, usefulness, and stickiness in students who used the Simulink tutor. With regards to robot lab assignment and quiz scores, the students who used the Simulink tutor performed significantly better than the students who did not use the Simulink tutor. In Table 3, when examining the perceived gains in higher order cognitive skills of students, higher perceived gains was observed in males and Caucasians who used the Simulink tutor versus those in the control group. It was observed that all the students who used the Simulink tutor performed at a higher level in the robot lab assignment than students who did not use the Simulink tutor. With regard to the robot lab quiz, males, minorities, and Caucasians who used the Simulink tutor performed at a significantly higher level than males, minorities, and Caucasians who did not use the Simulink tutor. Higher levels of perceived concentration, student enjoyment, perceived usefulness, and perceived stickiness were observed in males and Caucasians who used the Simulink tutor versus males and Caucasians who did not use the Simulink tutor. When examining perceived subject matter learning, higher levels of perceived subject matter learning was observed in Caucasians who used the Simulink tutor than Caucasians who did not use the Simulink tutor. In summary, all of the significant findings in this study revealed greater gains in both objective and subjective measures for students who used the Simulink tutor.

Units Tutor Evaluation

To test the relationships in Figure 4 for units tutor, independent *t*-tests (i.e., mean comparisons) were performed. The data in the following tables represent the results of the mean comparisons for several variables of interest across the control and experimental groups. *P*-values that were significant at the .05 level or smaller are highlighted (bold and italics) and reported. Further explanation is given for each of the significant results.

Table 13. Mean comparisons among several outcome variables of interest for Units tutor

Variables		M	SD	N	t	df	p
	Control	3.05	0.914	60	-1.479	115	.142

Higher Order Cognitive Skills	Experimental	3.28	0.760	57			
Concentration	Control	2.83	0.956	60	-2.256	115	***.026****
	Experimental	3.20	0.797	57			
Student Enjoyment	Control	2.83	0.946	60	-2.338	115	***.021****
	Experimental	3.23	0.918	57			
Goal Clarity	Control	3.30	0.840	60	-1.702	115	.091
	Experimental	3.56	0.792	57			
Perceived Subject Matter Learning	Control	2.99	0.858	60	-1.973	115	.051
	Experimental	3.29	0.768	57			
Perceived Usefulness	Control	3.03	0.894	60	-1.448	115	.150
	Experimental	3.26	0.761	57			
Perceived Stickiness	Control	2.76	0.888	60	-1.594	115	.114
	Experimental	3.01	0.806	57			
Units Quiz Score (Max 10)	Control	6.77	1.500	60	-5.410	115	***.000******
	Experimental	8.16	1.265	57			
Final Exam Units Score(Max 5)	Control	4.40	1.028	60	-0.211	115	.833
	Experimental	4.44	0.945	57			

Note. *p<.05, **p<.01, ***p<.001

The results in Table 12 revealed only three significant differences between mean scores. The overall mean perceived concentration scores of the control (μ = 2.83) and experimental (μ = 3.20) are found to be significantly different (p = .026). Also the overall mean perceived student enjoyment scores of the control (μ =2.83) and experimental (μ = 3.23) were significantly different (p = .021). Table 10 also shows that students' scores on the quiz were significantly different between the control (μ=6.77) and experimental (μ=8.16) groups, such that the experimental group displayed higher scores, (*p*=.000). These results suggest that the students in the experimental group improved their concentration and student enjoyment while using the units tutor and had significantly better units quiz scores when compared to control group.

Table 14. Mean Comparisons of Concentration for Gender and Race for the Unit Tutor

Variable	*Mean*	*Standard deviation*	*N*	*t*	*df*	*p*
Males concentration				-1.487	99	.140
Control	2.96	0.866	48			
Experimental	3.21	0.815	53			
Females concentration				-1.176	14	.259
Control	2.29	1.142	12			
Experimental	3.00	0.540	4			
Minority concentration				-5.333	10	***.000****
Control	1.00	0.000	2			
Experimental	3.30	0.587	10			
Caucasian concentration				-1.644	103	.103
Control	2.89	0.908	58			

Experimental	3.17	0.839	47

Note. *p<.05, **p<.01, ***p<.001

The results in Table 13 revealed only one significant difference between mean scores. The overall mean perceived concentration scores of the control (μ=2.83) and experimental (μ=3.20) groups were significantly different (*p*=.026). Additional analysis revealed that the relevant subgroup was the minority. Specifically, minorities in the control group (μ=1.00) had significantly lower scores than minorities in the experimental group (μ=3.30), (*p*=.000).

Table 15. Mean Comparison of Student Enjoyment (SE) for Gender and Race for the Units Tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males SE				-1.852	99	.067
Control	2.91	0.898	48			
Experimental	3.25	0.934	53			
Females SE				-0.840	14	.415
Control	2.50	1.097	12			
Experimental	3.00	0.736	4			
Minority SE				-4.979	10	***.001***
Control	1.12	0.177	2			
Experimental	3.47	0.639	10			
Caucasian SE				-1.600	103	.113
Control	2.89	0.906	58			
Experimental	3.18	0.965	47			

Note. *p<.05, **p<.01, ***p<.001

The results in Table 14 revealed only one significant difference between mean scores. After finding that the overall mean perceived student enjoyment scores of the control and experimental groups were significantly different (*p*=.026), additional analyses was conducted and found that the relevant subgroup was the minority. Specifically, minorities in the control group (μ=1.12) had significantly lower scores than minorities in the experimental group (μ=3.47), (*p*=.001).

Table 16. Mean Comparisons of Units Quiz Score (UQS) for Gender and Race for Units Tutor

Variable	*M*	*SD*	*N*	*t*	*df*	*p*
Males UQS				.263	99	***.000****
Control	6.77	1.387	48			
Experimental	8.19	1.194	53			
Females UQS				.613	14	.405
Control	6.75	1.960	12			
Experimental	7.75	2.217	4			
Minority UQS				.222	10	.637
Control	8.50	.707	2			
Experimental	7.90	1.603	10			
Caucasian UQS				.199	103	***.000****
Control	6.71	1.487	58			
Experimental	8.21	.1.178	47			

Note. *p<.05, **p<.01, ***p<.001

Two significant findings were revealed in Table 15. After finding that the overall mean Units Quiz Scores of control and experimental groups were significantly different (p = .000), additional analyses was conducted and found that the relevant subgroups were males and

Caucasians. Specifically, males in the control group (μ = 6.77) had significantly lower scores than males in the experimental group (μ = 8.19), (p =.000). In the Caucasian subgroup, it was observed that Caucasians in the control group (μ = 6.71) had significantly lower scores than Caucasians in the experimental group (μ = 8.21), (p = .000).

Summary and Findings from Units Tutor Evaluation

Table 17 summarizes the findings of the independent t-tests done for the Units tutor evaluation.

Table 17. Summary of Tables 12-15

Table #	Summary of results
Table 12	• Experimental group displayed significantly higher scores on concentration and student enjoyment measures than the control group • Experimental group Units Quiz Score (UQS) > Control group UQS
Table 13	• Experimental group minority CONC score > Control group minority CONC score
Table 14	• Experimental group minority SE score > Control group minority SE score
Table 15	• Experimental group male UQS > Control group male UQS • Experimental group Caucasian UQS > Control group Caucasian UQS

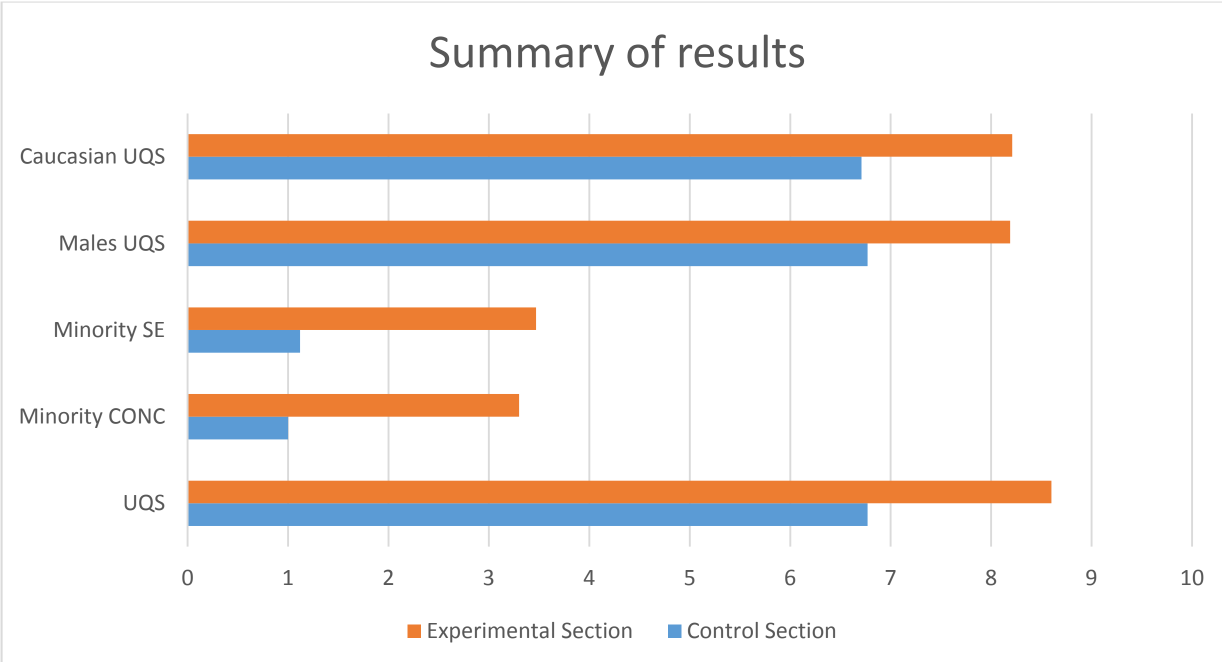

Figure 6. Table 16 in Graphical Form

Some significant mean comparisons during the data analysis were found. Beginning with Table 12, it was observed that the students who used the units tutor displayed higher perceived gains in concentration and student enjoyment than students who did not use the units tutor. In Table 13 and 14, higher levels of perceived concentration and student enjoyment were observed in minorities who used the units tutor versus minorities who did use the units tutor. With regards to the units quiz, it was observed that males and Caucasians who used the units tutor performed at significantly higher level than males and Caucasians who did not use the units tutor.

Qualitative

The students involved in this study were asked to provide an input regarding their experience with the tutor through a survey. The answers to the survey questions brought to light areas where the tutor can be improved. These areas include voice used, video speed, game quality, and material details that should be included. This evaluation helps improve the tutor so that it meets the students' needs and learning styles. In this way, the production is student-centered and involves them in the process of creating the applications.

The control section students' mean UQS is 6.77 whereas the mean UQS of experimental section students' is 8.17. Many students in the control section expressed negative comments about the ULM 1, which did not include the concept tutor. "Didn't find the learning module very helpful—had seen this for many years beforehand and the material wasn't presented in a new or intriguing way. Felt it really hard to concentrate on if I didn't feel as if I was learning anything new" was one such comment. This clearly necessitates a change in conventional lectures.

Open-ended responses were collected from the students while testing Simulink and units tutor. Students learned about programming the LEGO robots using the Simulink tutor and about unit conversions using the units tutor. Students found the use of Simulink and units tutor beneficial. One student said, "I felt like the presentation of information was fine. I liked the idea of games instead of simple tests." Students indicated that the tutors were fun and enjoyable. Another student expressed that "The Simulink robot labs were definitely my favorites so far. The programing was very informative and well taught." Student comments also indicated that the Simulink tutors provided a challenging and problem-solving environment. A student commented, "Units are an important and vital aspect, but I feel that this module would be much more beneficial at the beginning of the course as it is easy and most people already understand units."

As a benefit for the tutor, the instructors conducting the learning modules reported a shift in the type of questions the students asked while working on their assignment. Table 17 shows the questions answered by the instructors.

Table 18: Questions asked by the students to the Instructors

Questions	E1	E2	E3	C1	C2	C3
Logical	H	H	H	H	H	H
Basic (how to open file, save, run)	L	L	L	L	L	H
Operation of Robot (navigation within the CPU brick of Robot)	L	L	L	L	L	M
Simulink environment (connecting blocks, zoom in/out, copy)	L	L	L	L	M	M
Questions on Chart (creating inputs outputs)	L	L	L	H	H	M

E1, E2 and E3 are the three experimental sections, and C1, C2 and C3 are the three control sections. H, M and L refers to high, medium, and low frequency of questions on the related field asked by the students to the instructors while solving their assigned problems. The students' questions in the experimental sections were focused toward the logical problems in their assignment, while the students in the control sections required more guidance with the interface.

Conclusion

Students who feel overwhelmed with lecture material need additional support by refreshing the prerequisite concepts upon which the course is built. A concept tutor is a step-by-step learning material with a game and a self-assessment tool incorporated. Our work explains the development, implementation and evaluation of Simulink and units tutor. This study evaluates the effectiveness of the concept tutors using a 4P model. Both the qualitative and quantitative results show that the students enjoyed the concept tutors. It was observed that students perform and learn better when they use concept tutors. Students perceive to work with higher levels of concentration with the concept tutors. Males and Caucasians perceive better learning outcomes and reacted very positively to the use of concept tutors in the class. This study can encourage instructors to create more concept tutors to teach complex engineering concepts so as to improve students' understanding of concepts and problem-solving skills.

Chapter 3

Evaluation of Courses in an Ecological Engineering Spiral Curriculum

Purpose of this Study

Engineering students are expected to acquire higher order cognitive skills, categorized by Bloom as synthesis and evaluation, at the end of a course, although in most cases the instructional materials provided to the students concentrate on lower level skills, knowledge, comprehension, and application [13]. Expecting students to gain skill levels which are not taught by the instructors is not reasonable [13]. The objective of this study is to evaluate two undergraduate level engineering courses in spiral curriculum in terms of their learning objectives, the ideal skills to be attained, and the actual skills attained by the students. Ecological engineering is one of the three pathways to opt within the biosystems engineering undergraduate degree program at Auburn University [19]. Some of the program objectives are “Graduates develop solutions to problems that combine engineering and biological sciences” and “Graduates develop environmentally and economically feasible and practical design solutions.” The courses under analysis are Hydraulic Transport in Biological Systems (BSEN 3310) and Geospatial Technologies in Biosystems (BSEN 5220). The course objectives of these courses are:

1. Provide basic and practical understanding of fluid properties of fluids (including non-Newtonian fluids) at rest and in motion. (BSEN 3310)
2. Solve problems that biological systems engineers are expected to encounter in their professional careers. (BSEN 3310)

Prepare students for other related biological systems engineering curriculum courses, which are dependent on hydraulic/fluids principles and applications. (BSEN 3310)

Research Questions

1. How should each skill level—namely knowledge, comprehension, application, analysis, synthesis, and evaluation—be weighted for the BSEN 3310 and BSEN 5220 level courses in terms of the way the exam questions measure these levels?
2. How to evaluate the differences between the ideal skills to be attained by the students to the actual skills attained by the students as measured by their performance on final exam?

Significance

In the field of engineering, Arens, Hanus, and Sakilis have posited that students acquire the lowest skill levels, knowledge, and comprehension in their first-year courses and progress in their program to attain the highest levels, synthesis, and evaluation [20]. The evaluation presented here gives the instructors an idea of where their learning objectives have to concentrate and helps provide feedback to the design of the spiral curriculum as a whole to have a positive impact on the students' skill levels. This study aims at aligning instruction material toward learning objectives set by the instructors and to have student assessment that corresponds to the learning objectives. The student assessment results can then be used to modify the instruction for a better alignment toward the learning objectives.

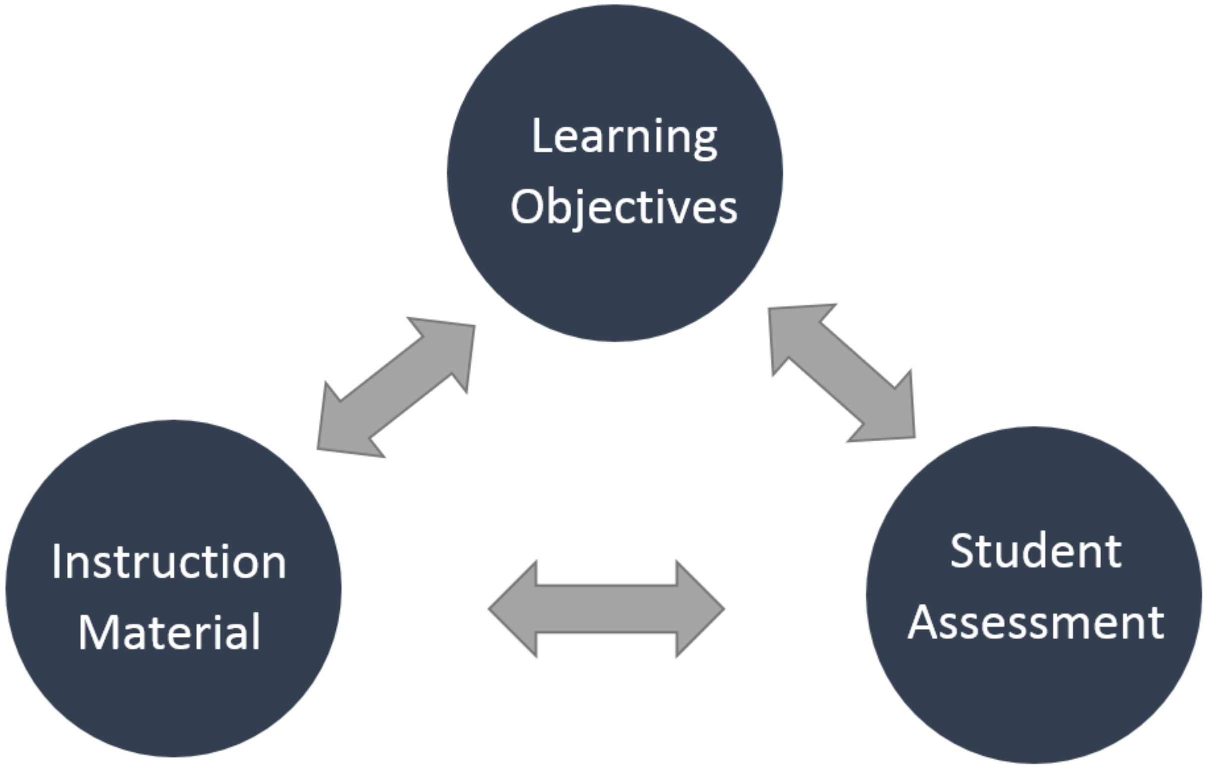

Figure 7. Alignment of instructional material and student material toward learning objectives

Assessment Criteria

Learning Objectives

In order to achieve the mission of a curriculum, the course learning objectives are very important [21]. Learning objectives are statements made by the instructors to the students of what they will be able to do at the end of a course or a unit of study. Setting up learning objectives for a course is very important as it dictates the instruction material and learning outcomes. S.M.A.R.T. strategy could prove useful in this process [22]. Learning objectives should be

1. Specific—by giving specific statements to students of what the course teaches
2. Measurable—in terms of what the students can achieve through the course
3. Achievable—by the students at the end of a course. Learning objectives should not be beyond the scope of understanding of the students

4. Realistic—in a way that it should be challenging and have more probability of succeeding
5. Time bound—which would allow both the instructors and students to complete within the specified time.

Bloom's taxonomy

Different learning objectives require different skill levels, with some objectives requiring only memorization while others requiring ingenuity and imagination. [13] The taxonomy of educational objectives was developed by Benjamin Bloom in the 1950s as an effort to classify the learning objectives set by the instructors. This taxonomy divides learning objectives into three domains: cognitive, affective and psychomotor. This study concentrates on the cognitive domain. The skills in cognitive domain require knowledge and intellectual ability. The cognitive domain is further divided in six categories starting from knowledge, comprehension, and application—which are considered as lower-order skills—to analysis, synthesis, and evaluation, considered as higher order skills. The original version of categories of cognitive domain is explained below [12].

Table 19. Categories of Cognitive Domain

Skill	Key Words
Knowledge - This is the first level of the cognitive domain. Memorize materials and recall facts, basic concepts, formulae etc.	arranges, defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states
Comprehension - This level of cognitive domain exhibits the understanding of basic concepts and ideas.	Comprehends, converts, diagrams, defends, distinguishes, estimates, explains, extends, generalizes, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarizes, and translates.
Application - Apply attained knowledge for solving problems in different situations	applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses.
Analysis - Analyze information presented and identify causes and results. Make statements to provide evidence.	analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, and separates.
Evaluation - Make and defend statements by providing valid information and criteria.	appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes,

	discriminates, evaluates, explains, interprets, justifies, relates, summarizes, supports.
Synthesis - Assemble facts and information together in a different way by combining elements and propose new solutions.	categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes

The keywords corresponding to each skill is used to categorize the questions that test these skills.

ABET

Accreditation Board for Engineering and Technology (ABET), guarantees quality and encourages creativity among applied science, computing, engineering, and engineering technology education [23]. ABET specifies a set of skills for each engineering curriculum that students should be trained and tested. ABET assessment methods for some of the criterion of the engineering curriculum under study along with cognitive domain categories are listed in the table below.

Table 20. Assessment Method for ABET Criteria

ABET Criterion	Cognitive domain category	Assessment Method	
		BSEN 3310	BSEN 5220

Knowledge of science, math and engineering	Knowledge and Comprehension	Mid-term and Final exam	Mid-term and Final exam
Design, conduct, experiments, analyze, interpret data	Evaluation and Synthesis	Rheology Lab	Mid-term,Final exam, GPS Lab I and II
Design a system, component or process	Application and Analysis	Mid-term and Final exam	Mid-term and Final exam
Identify, formulate and solve engineering problems	Application	Mid-term and Final exam	Mid-term and Final exam

In BSEN 3310, mid-term and final exams test the knowledge, comprehension, application and analysis whereas in BSEN 5220, mid-term and final exams test all the categories of the cognitive domain except evaluation.

Methods

The two undergraduate level ecological engineering courses considered for this study are BSEN 3310 and BSEN 5220. Evaluation data is the midterm and final exam scores of the students. In order to have a sample size of 97 (close to 100), students' scores from mid-term and final exams of BSEN 3310 taught in 2010, 2011, 2012 and 2013 are used. Similarly the students' scores of mid-term and final exams of BSEN 5220 in 2010, 2011 and 2013 are used. Each question and sub-question in these exams are assigned a skill type which will be required by the students to solve that question. This skill mapping is based on the Bloom's taxonomy criterion and key words listed in the previous sections. The instructor of each course validated the mapping of skills to the questions. Midterm and final exams were considered. Total number of students' scores assessed is 107 in BSEN 3310 and 97 in BSEN 5220. Table III explains how the questions are categorized in the final exam for BSEN 5220 in 2011. Similar tables are generated for the exams mentioned above for both the courses. The table also has the scores of students for each sub question. A student's score is shown for reference.

Table 21. Mapping of Cognitive Skills to Questions

Year	Exam	Total Score	Question No:	Skill tested	Max Score	Student Score
2011	Final	100	1	Comprehension	3	3
				Knowledge	2	2
				Comprehension	2	0
				Knowledge	2	0
			2	Knowledge	3	3
				Application	3	2
			3	Analysis	5	2
			4	Comprehension	3	2
			5	Comprehension	4	3

				Analysis	2	0
				Knowledge	3	2
			6	Synthesis	5	3
			7	Knowledge	4.5	1.5
				Comprehension	3	3
			8	Analysis	3	3
			9	Application	2	0
				Knowledge	2	0
			10	Comprehension	3	3
				Comprehension	3	1.5
			11	Knowledge	2	2
			12	Knowledge	4.5	0
			13	Knowledge	5	3
			14	Knowledge	2	1
			15	Analysis	3	0
			16	Knowledge	6	6
				Analysis	2	2

			17	Comprehension	3	3
				Knowledge	3	0
			18	Knowledge	2	2
			19	Synthesis	6	4
			20	Analysis	4	3

Analysis Process

Different courses expect students to attain different cognitive skills based on the learning objectives. The instructors of each course are asked for the weights on each skill that the students' should possess. They came up with the following weights based on their course learning objectives and ABET criteria. The conditions set on the weights were that the sum of the weights should be 10 and none of the individual weights can be more than 4. This makes the weight distribution not inclined towards a particular skill. They also considered the fact that this analysis is based on the mid-term and final exams and does not include other assignments, projects or lab activities.

Table 22. Weights of Cognitive Skills

Skill Types	BSEN 3310	BSEN 5220
Knowledge	2	3
Comprehension	3	2
Application	4	2

Analysis	1	2
Synthesis	0	1
Evaluation	0	0
Total	10	10

The number '4' against application skill for BSEN 3310 means this course requires students to develop more application skill than other skills. Students' scores for the exams mentioned are collected and a table is generated with their scores for each sub question. A sample table of scores is shown in results section.

Results

Based on the student's score shown on table III, the percentage score against each skill type is calculated. Ideal score is assumed to be 100%. The difference in these numbers is the percentage by which the student lacks that particular skill. This is represented as "Percentage Deviation from Ideal". This difference is multiplied by the weight assigned to the skill and divide it by the total weight (10). This represents the "Normalized Deviation from Ideal".

Table 23. Normalized Difference of a Student's Score from Ideal Score in BSEN 5220

Cognitive Skills	Student's Score	Max Score	Percentage Score	Percentage Deviation from Ideal	Normalized Deviation from Ideal
Knowledge	21.5	38.00	56.58	43.42	13.03
Comprehension	18.5	24.00	77.08	22.92	4.58

Analysis	10	19.00	52.63	47.37	9.47
Application	2	5.00	40.00	60.00	18.00
Synthesis	5	8.00	16.00	84.00	8.40

This process is performed for all the students in the courses under study and an average normalized deviation from ideal score is obtained for each cognitive skill in each course.

BSEN 3310

The sample size of this course evaluation is 107 students.

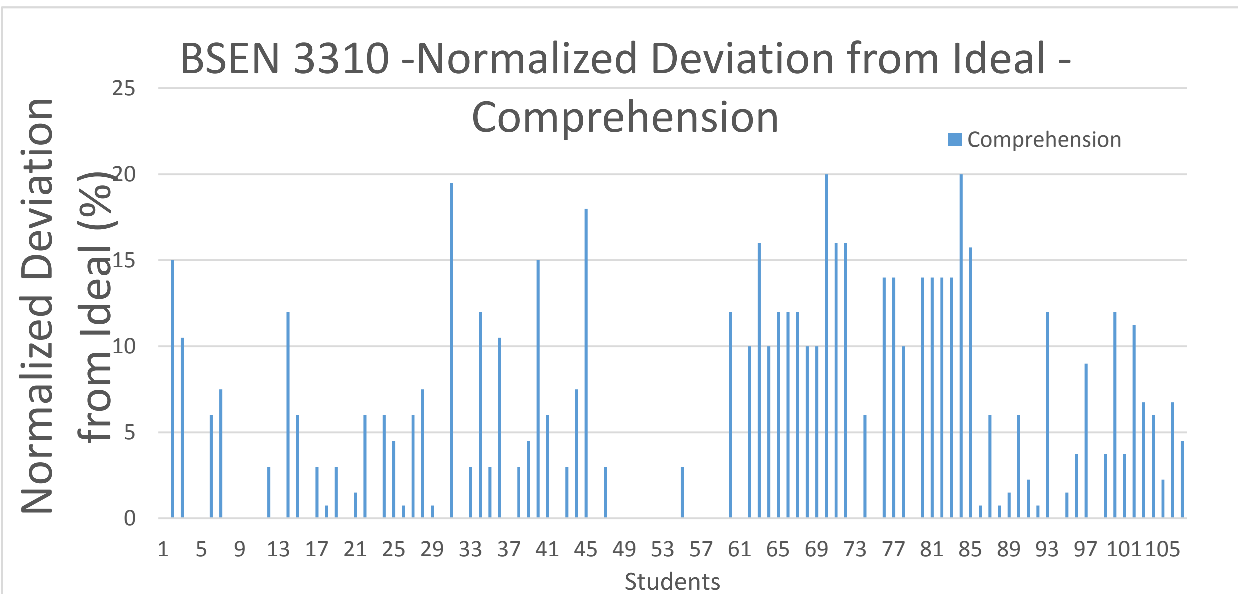

Figure 8. BSEN 3310 - Normalized Deviation from Ideal - Comprehension

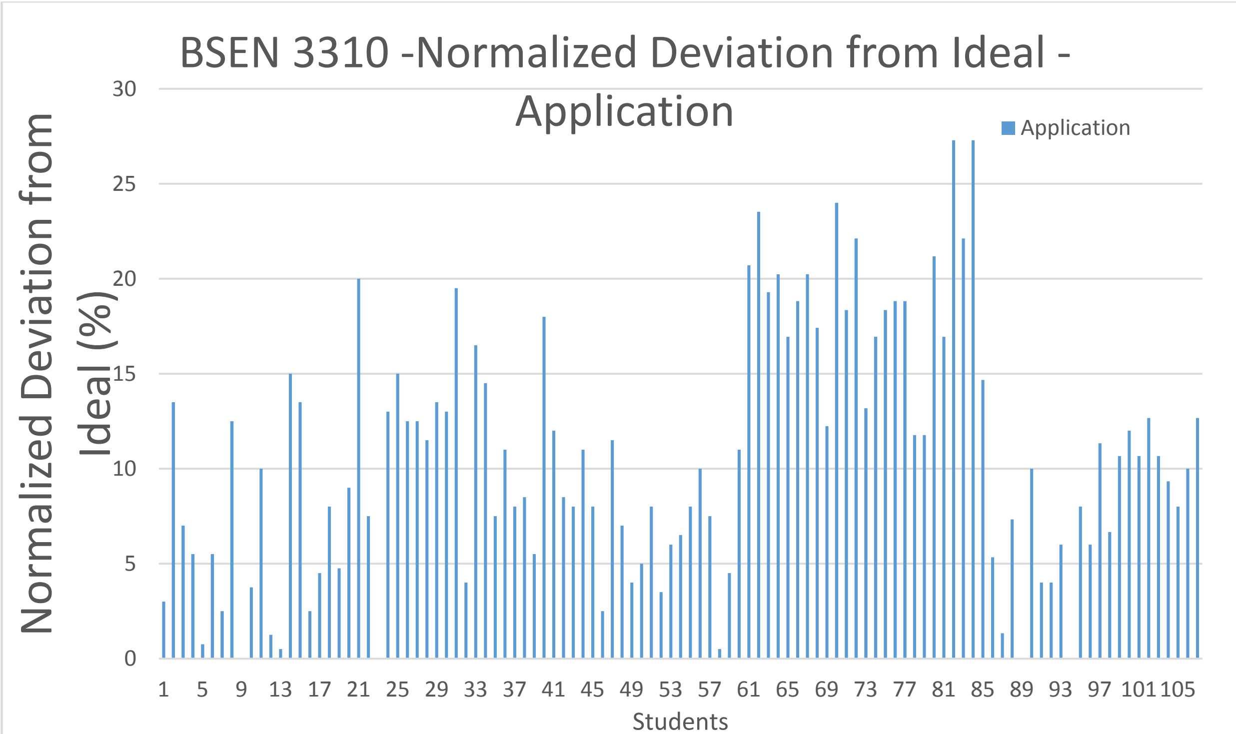

Figure 9. BSEN 3310 - Normalized Deviation from Ideal - Application

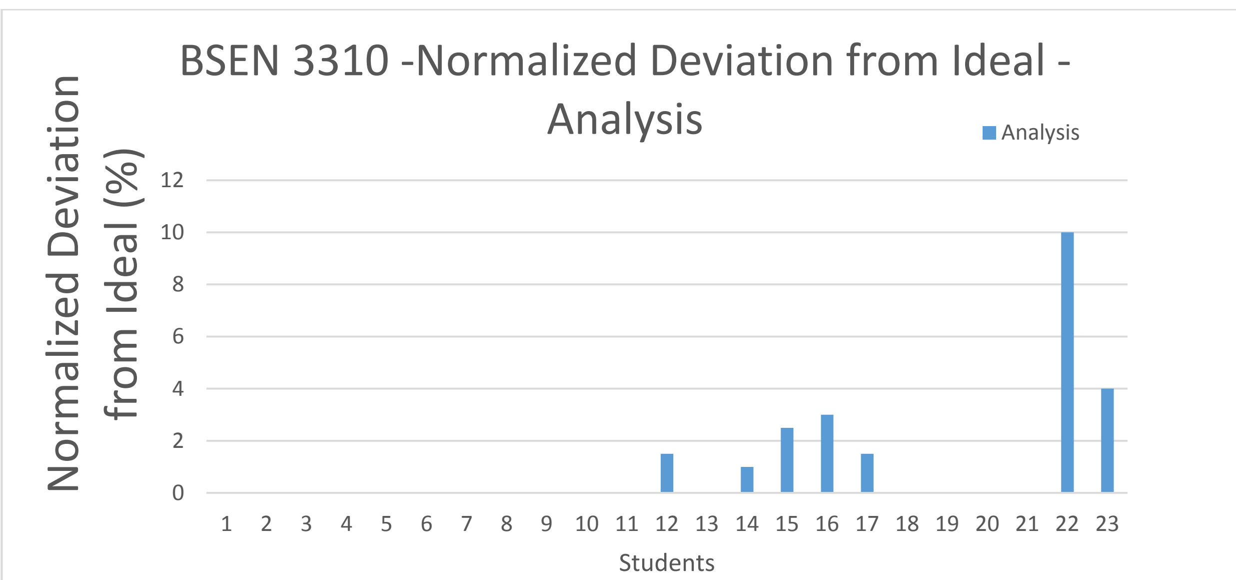

Figure 10. BSEN 3310 - Normalized Deviation from Ideal - Analysis

The cognitive skill, analysis, was tested only during the mid-term exam of 2012. Hence the sample size for this skill type is 23.

Below is the Normalized deviation from ideal scores of skill levels of the total sample for BSEN 3310 course. The weights for the skills synthesis and evaluation are zero for this course.

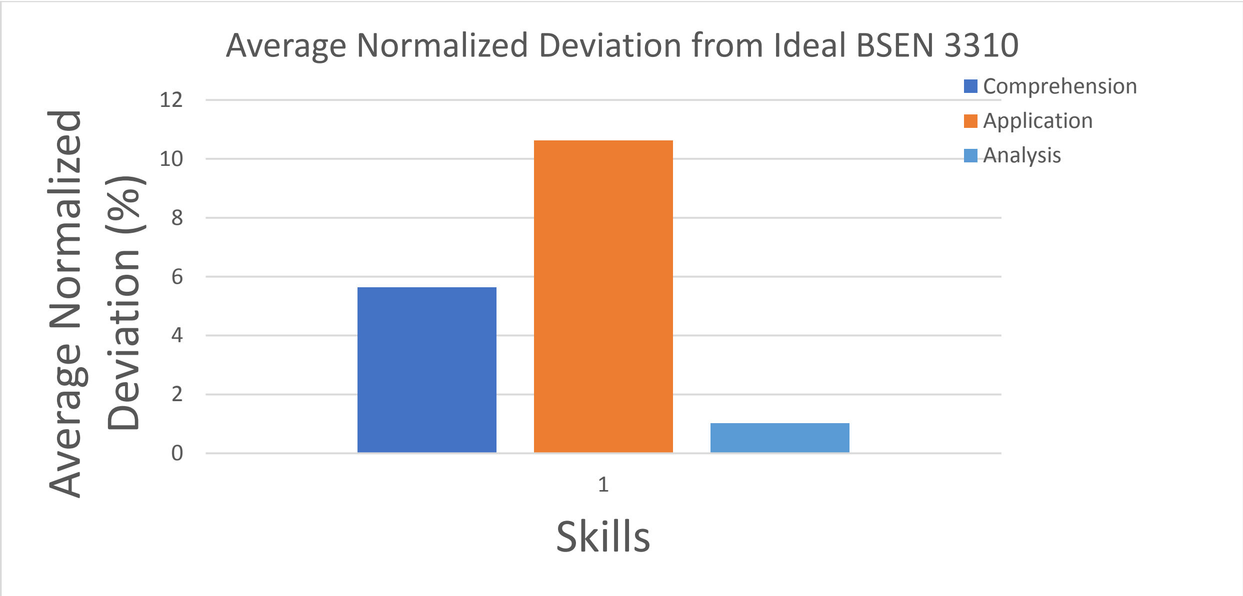

Figure 11. BSEN 3310 – Average Normalized Deviation from Ideal

This indicates the students need to score 10.5% more in application level questions to make the “Average Normalized Deviation from Ideal” value zero. The other point to note is that the exam does not test the skill level knowledge in spite of giving it a weight of 2 (on 10).

BSEN 5220

The sample size for BSEN 5220 is 97 students. Normalized Deviation from Ideal is calculated for each student corresponding to each cognitive skill.

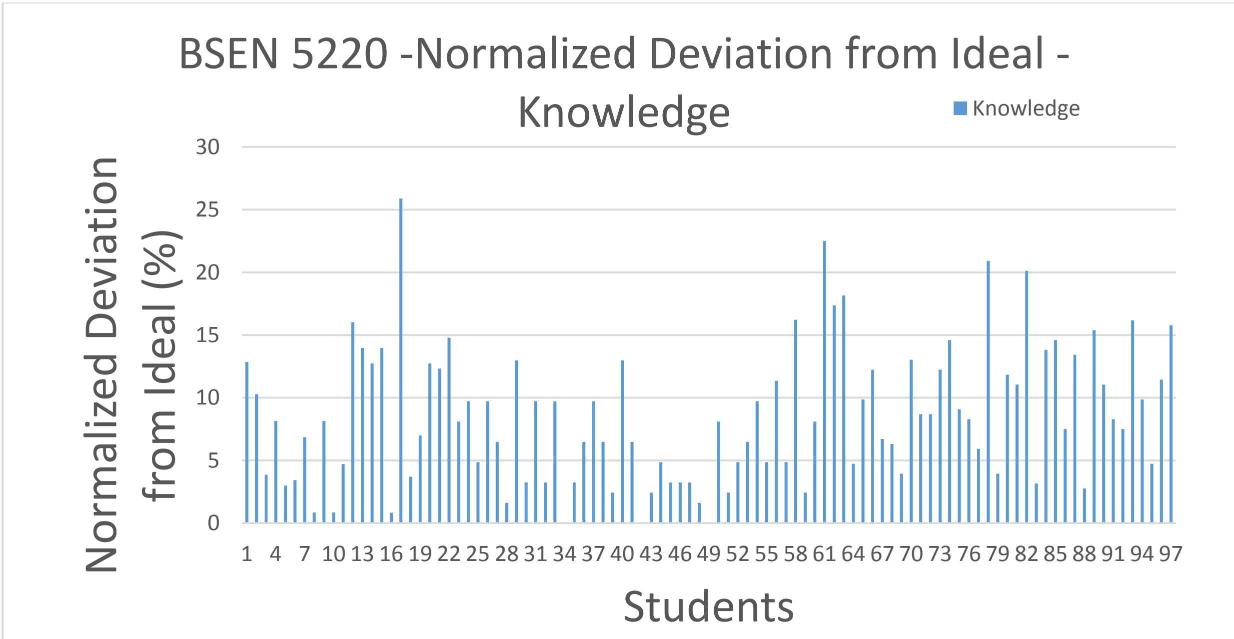

Figure 12. BSEN 5220 - Normalized Deviation from Ideal - Knowledge

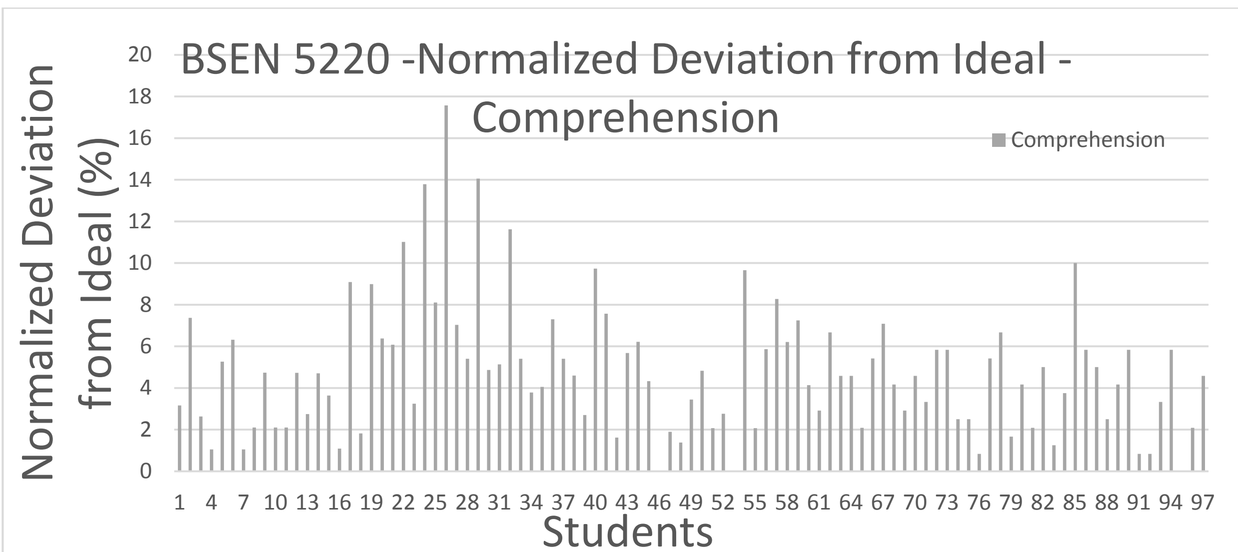

Figure 13. BSEN 5220 - Normalized Deviation from Ideal - Comprehension

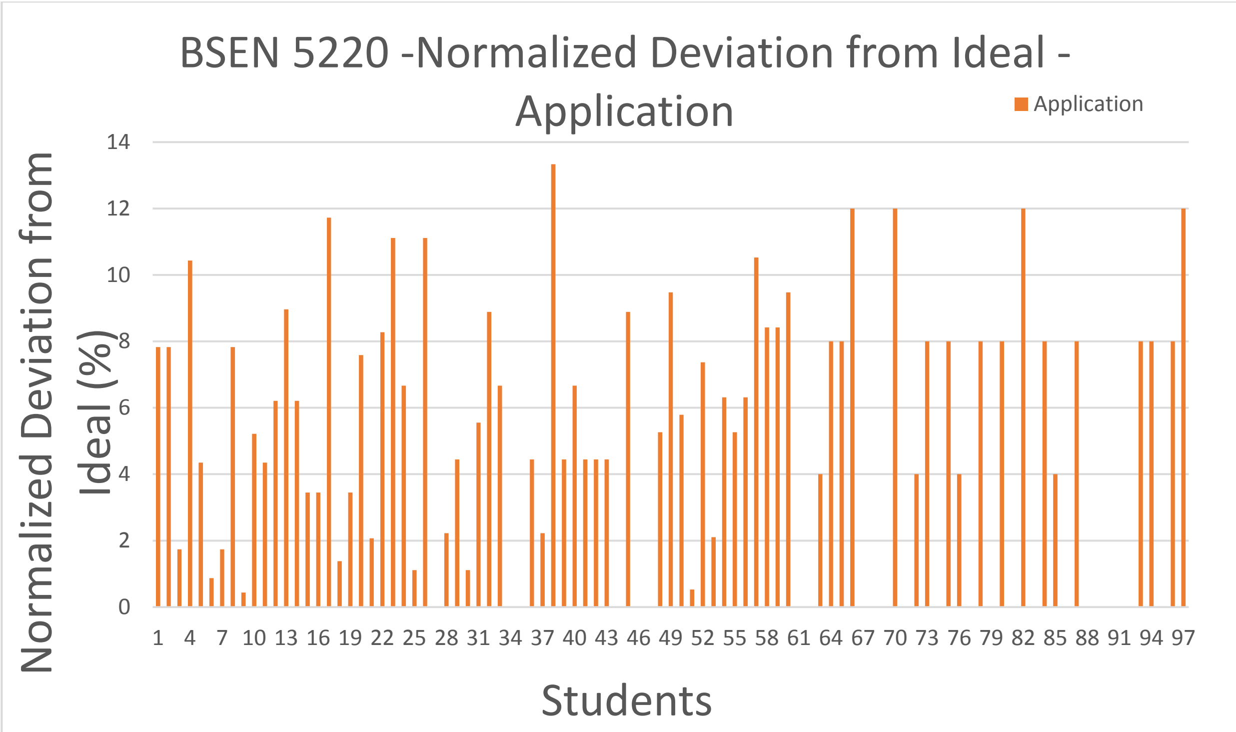

Figure 14. BSEN 5220 - Normalized Deviation from Ideal – Application

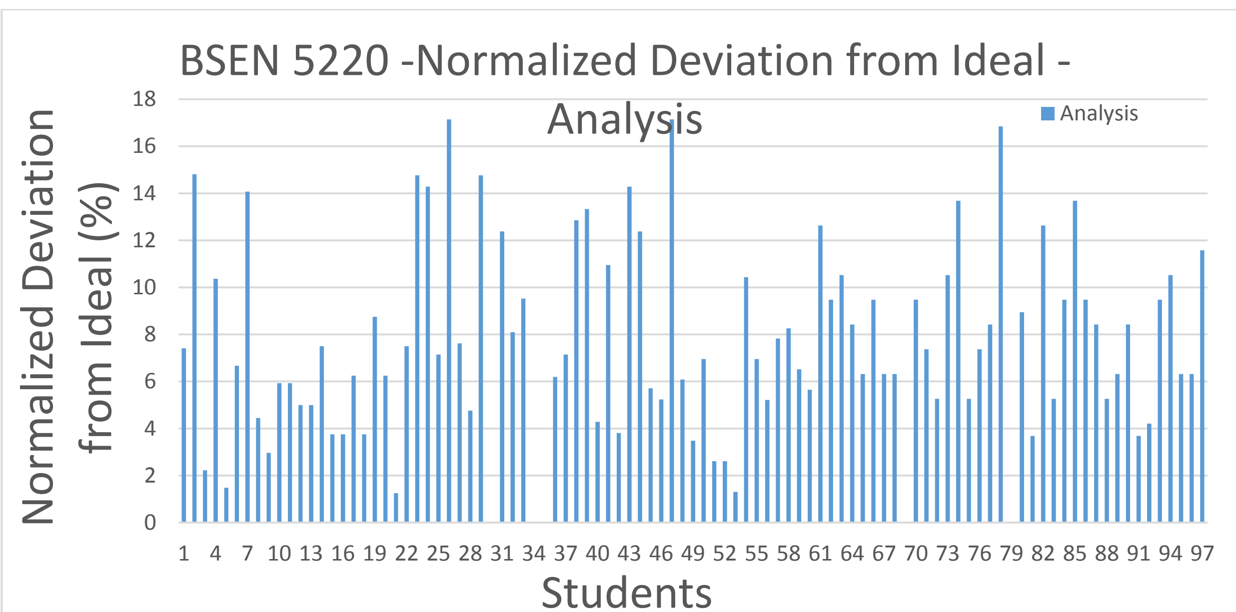

Figure 15. BSEN 5220 - Normalized Deviation from Ideal - Analysis

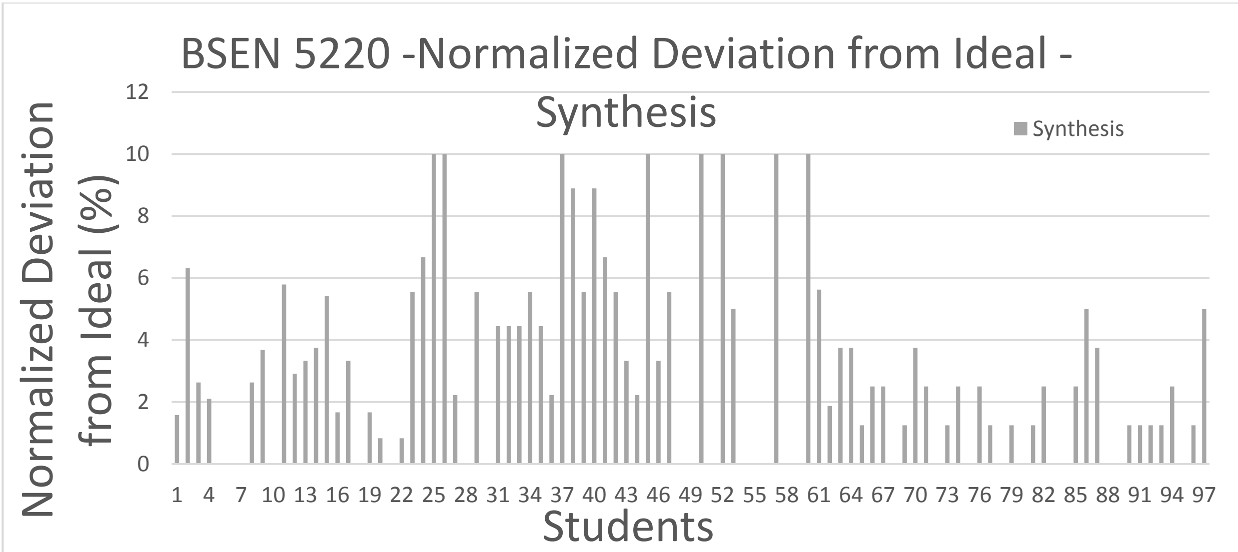

Figure 16. BSEN 5220 - Normalized Deviation from Ideal - Synthesis

Figure 15 shows the average normalized deviation from ideal scores of skill levels of the total sample for BSEN 5220 course. The weight for skill evaluation is zero for this course.

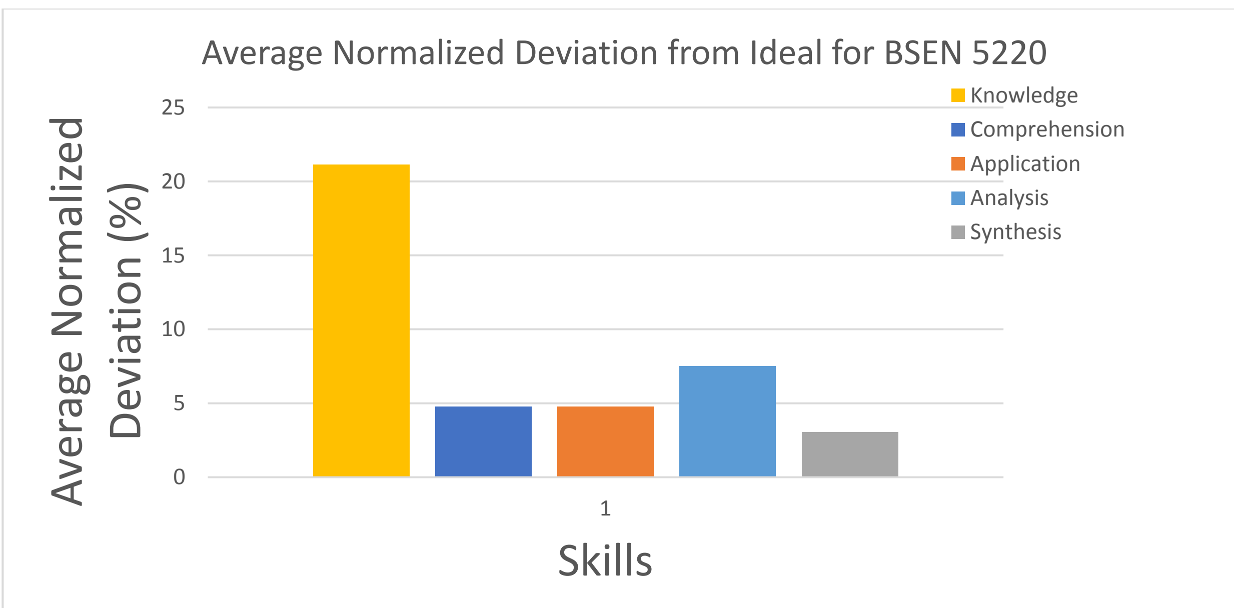

Figure 17. BSEN 5220 – Average Normalized Deviation from Ideal

This indicates the students need to score 21% more in knowledge-level questions to achieve their ideal score of 100%. This also means that the course should teach things that will help in achieving this target.

Discussion

From the “percentage deviation from ideal” of knowledge and synthesis in table V, one might say that student did not perform well in synthesis, but from “normalized deviation from ideal” it could be argued the other way. This is entirely based on the weights given to each skill. The “Average Normalized Deviation from Ideal” of BSEN 3310 indicates the instruction material should focus on improving the application skill of the students which will help them achieve zero “Average Normalized Deviation from Ideal”. In BSEN 5220, the instruction material should focus on improving knowledge skill that would enable students to attain zero “Average Normalized Deviation from Ideal”.

Conclusions

This analysis helps instructors to identify the gaps between the learning objectives and the instruction material and modify the material to meet the ABET criteria and learning objectives. The student assessment should focus on the learning objectives.

Future work on this study could be done through similar analysis of the students’ scores on other assessment methods on these courses like quizzes, assignment and lab activities. This will further enhance the average normalized deviation for each cognitive skill.

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APPENDICES

Appendix 1

Auburn University Institutional Review Board (IRB) Approval

AUBURN
UNIVERSITY

College of Business

Department of Aviation
and Supply Chain Management

The Auburn University Institutional Review Board has approved this document for use from 1/13/14 to 12/28/14 Protocol # 11-380 EP 1112

(NOTE: DO NOT SIGN THIS DOCUMENT UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)

INFORMED CONSENT
for a Research Study entitled
"The Design and Testing of Serious Games in Technical Disciplines"

Your child is invited to participate in a research study to determine the extent to which serious games, as an instructional methodology, improve student outcomes, motivate students to persist in their current discipline, and provide benefits beyond traditional instructional methodologies. The study is being conducted by Chetan S. Sankar in the Auburn University Department of Aviation & Supply Chain Management. Your child was selected as a possible participant because you are enrolled in an engineering course or another technical course. Since your child is age 18 or younger we must have your permission to include him/her in the study.

If you decide to allow your child to participate in this research study, your child will be asked to complete a pre- and post- survey, as well as an end of semester survey. Your child's total time commitment will be approximately 15-20 minutes per survey. In addition, we are asking to use your child's grades on class projects and tests, in a confidential manner, for this study.

The risk associated with participating in this study is a potential breach of confidentiality. To minimize this risk, we will separate all of your child's identifiable information from his/her survey responses and store them, electronically, on two separate computers in password protected files. All identifiable information will be kept confidential and will not be made available to any third parties for any reason.

If your child participates in this study, they can expect to receive feedback regarding the results of this study, if requested.

If you or your child changes your mind about participating, your child can be withdrawn at any time during the study. Your child's participation is completely voluntary. If you choose to withdraw your child, your child's data can be withdrawn as long as it is identifiable. Your decision about whether or not to allow your child to participate or to stop participating will not jeopardize your or your child's future relations with Auburn University, the researchers involved in this study, or the Department of Aviation & Supply Chain Management.

415 W. Magnolia Avenue
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Telephone:
334-844-4908
Fax:
334-844-4927

Any information obtained in connection with this study will remain confidential. Information obtained through your child's participation may be used to fulfill an education requirement, published in a journal, or presented at a professional meeting.

If you or your child have any questions about this study, please ask them now or contact Chetan S. Sankar at sankacs@auburn.edu, or Justin L. Bond at justin.bond@auburn.edu. A copy of this document will be given to you to keep.

If you have questions about your child's rights as a research participant, you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH FOR YOUR CHILD TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS ALLOW YOUR CHILD TO PARTICIPATE. YOUR CHILD'S SIGNATURE INDICATES HIS/HER WILLINGNESS TO PARTICIPATE. YOU MAY PROCEED TO SIGN THE FORM.

______________________ Date Participant's signature	C Sankar ______________________ Date Investigator obtaining consent
______________________ Printed Name	CHETAN S. SANKAR ______________________ Printed Name
______________________ Date Parent/Guardian Signature	
______________________ Printed Name	

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If you decide to participate in this research study, you will possibly be asked to participate in a focus group. Your total time commitment will be approximately 45 minutes.

The risk associated with participating in this study is a potential breach of confidentiality. To minimize this risk, we will separate all of your identifiable information from your focus group responses and store them, electronically, on two separate computers in password protected files. All identifiable information will be kept confidential and will not be made available to any third parties for any reason. While the participants involved in the focus groups will be encouraged to keep discussion information private, we cannot guarantee the confidentiality of discussions.

If you participate in this study, you can expect to receive feedback regarding the results of this study, if requested.

If you change your mind about participating, you can withdraw at any time during the study. Your participation is voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the researchers involved in this study, or the Department of Aviation & Supply Chain Management.

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Participant's signature Date	Investigator obtaining consent Date
Printed Name	CHETAN S. SANKAR Printed Name

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for a Focus Group Research Study entitled
"The Design and Testing of Serious Games in Technical Disciplines"

Your child is invited to participate in a research study to determine the extent to which serious games, as an instructional methodology, improve student outcomes, motivate students to persist in their current discipline, and provide benefits beyond traditional instructional methodologies. The study is being conducted by Chetan S. Sankar in the Auburn University Department of Aviation & Supply Chain Management. Your child was selected as a possible participant because you are enrolled in an engineering course or another technical course. Since your child is age 18 or younger we must have your permission to include him/her in the study.

If you decide to allow your child to participate in this research study, your child will possibly be asked to participate in a focus group. Your child's total time commitment will be approximately 45 minutes.

The risk associated with participating in this study is a potential breach of confidentiality. To minimize this risk, we will separate all of your child's identifiable information from his/her survey responses and store them, electronically, on two separate computers in password protected files. All identifiable information will be kept confidential and will not be made available to any third parties for any reason. While the participants involved in the focus group will be encouraged to keep discussion information private, we cannot guarantee the confidentiality of discussions.

If your child participates in this study, they can expect to receive feedback regarding the results of this study, if requested.

If you or your child changes your mind about participating, your child can be withdrawn at any time during the study. Your child's participation is completely voluntary. If you choose to withdraw your child, your child's data can be withdrawn as long as it is identifiable. Your decision about whether or not to allow your child to participate or to stop participating will not jeopardize your or your child's future relations with Auburn University, the researchers involved in this study, or the Department of Aviation & Supply Chain Management.

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AUBURN, AL 36849
TELEPHONE: 334-844-4908
FAX: 334-844-4927
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Participant's initials ______

Any information obtained in connection with this study will remain confidential. Information obtained through your child's participation may be used to fulfill an education requirement, published in a journal, or presented at a professional meeting.

If you or your child have any questions about this study, please ask them now or contact Chetan S. Sankar at sankacs@auburn.edu, or Justin L. Bond at justin.bond@auburn.edu. A copy of this document will be given to you to keep.

If you have questions about your child's rights as a research participant, you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH FOR YOUR CHILD TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS ALLOW YOUR CHILD TO PARTICIPATE. YOUR CHILD'S SIGNATURE INDICATES HIS/HER WILLINGNESS TO PARTICIPATE. YOU MAY PROCEED TO SIGN THE FORM.

Participant's signature Date	C Sankar Investigator obtaining consent Date
Printed Name	CHETAN S. SANKAR Printed Name
Parent/Guardian Signature Date	
Printed Name	

Page 2 of 2

Appendix 2

Simulink Tutor

Simulink Tutor Survey

Simulink Tutor

Please answer the following to the best of your knowledge regarding the series of videos activity during the lab.

Q1 CODE (Please find the numerical code on Canvas in Grades under the tag CODE)

Q2 What Game did you play?
- ❍ No game (1)
- ❍ Boid game (2)
- ❍ Connect Game (3)

Q3 What was your score (if recorded)

Q4 How long did it take you to go through the material?(if recorded)

Q5 Did you skip any videos?
- ❍ Yes (1)
- ❍ No (2)

Q6 If you answered yes tot he previous question, how many videos did you skipped?

Q7 How many questions did you answer?

Q8 How many questions were correctly answered?

Q9 Please rate the following

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
How easy was it to learn concepts this way? (1)	❍	❍	❍	❍	❍
How well did you enjoy it as a learning tool? (2)	❍	❍	❍	❍	❍
Would you like to learn/refresh more course concepts this way? (3)	❍	❍	❍	❍	❍
Was this a fun way to learn concepts as compared to ways you've learnt in the past? (4)	❍	❍	❍	❍	❍
Would you like to learn engineering concepts in this way more often? (5)	❍	❍	❍	❍	❍
Was the explanation of the concept clear and thorough? (6)	❍	❍	❍	❍	❍
Does the presentation style add to understanding the material? (7)	❍	❍	❍	❍	❍
Was the narration too fast? (8)	❍	❍	❍	❍	❍

Do you understand the concept better after completing the activity? (9)	❍	❍	❍	❍	❍
Was the narration too slow? (10)	❍	❍	❍	❍	❍
How was quality of the video? (11)	❍	❍	❍	❍	❍
Was the sound clear? (12)	❍	❍	❍	❍	❍
Do you prefer this method over reading a textbook? (13)	❍	❍	❍	❍	❍
Do you prefer this method over listening to lecture? (14)	❍	❍	❍	❍	❍
Do you prefer this method over doing traditional homework? (15)	❍	❍	❍	❍	❍
How easy was it to maneuver through? (16)	❍	❍	❍	❍	❍
Would you like to have this method as a supplement to go with the lecture? (17)	❍	❍	❍	❍	❍
Were the instructions clear for the gaming part? (18)	❍	❍	❍	❍	❍

Was the gaming part fun? (19)	❍	❍	❍	❍	❍
Do the exercises vary in difficulty? (20)	❍	❍	❍	❍	❍
Are the exercises matching the explanation? (21)	❍	❍	❍	❍	❍

Q10 Overall, how would you rate your experience in the scale of 1-5?
- ❍ 1 (1)
- ❍ 2 (2)
- ❍ 3 (3)
- ❍ 4 (4)
- ❍ 5 (5)

Q11 Did you have any prior knowledge of how to use Simulink?
- ❍ Yes (1)
- ❍ No (2)

Q12 Please name a few concepts/lessons/ideas you learned from the Tutor App?

Q13 What did you feel was the best aspect of learning this way?

Q14 What was the worst aspect of learning this way?

Q15 Comments and suggestions:

Q16 Thank you !

Robot Lab Survey

TutorSimulinkSpring2014

Q1 The Simulink learning module includes materials covered during lecture and in the lab as well as the following activities that you performed. 1. Lecture on Robots (PowerPoint presentation done by instructor)2. Active Learning Exercise (Introduction to SImulink and Robot Mindstorm NXT programming by the TA in the lab, or Introduction to SImulink and Robot Mindstorm NXT programing using a video/game-based exercise)

Q2 Please enter the number provided by your lab instructor

Q3 Please select your lab section from the list below
- ❍ 13 (1)
- ❍ 14 (2)
- ❍ 15 (3)
- ❍ 20 (4)
- ❍ 21 (5)
- ❍ 31 (6)

Q4 Gender
- ❍ Male (1)
- ❍ Female (2)

Q6 Major
- ❍ Business or sub-discipline (1)
- ❍ Engineering or sub-discipline (2)
- ❍ Other (please list) (3) ____________________

Q7 Status
- ❍ Freshmen (1)
- ❍ Sophomore (2)
- ❍ Junior (3)
- ❍ Senior (4)
- ❍ Graduate Student (5)

Q8 Race

- ❍ White (1)
- ❍ African-American (2)
- ❍ Hispanic (3)
- ❍ Asian-American (4)
- ❍ American Indian (5)
- ❍ Other (6)

Q9 Did you have any previous knowledge about programing using Simulink?

- ❍ Yes (1)
- ❍ No (2)

Q10 Did you have any previous knowledge about programing a robot?

- ❍ Yes (1)
- ❍ No (2)

Q11 If you answered "yes" to the previous question, please list the environment or software used in programing a robot.

Q12 Please rate the degree to which you agree with the following statements in this questionnaire by bubbling in or clicking on the response according to the following 5-point-scale

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
The instructional materials in the Simulink learning module helped me identify logical tools that will assist me in decision-making (1)	❍	❍	❍	❍	❍
My attention was focused on the Simulink learning module (2)	❍	❍	❍	❍	❍
I enjoyed many aspects of this learning module (3)	❍	❍	❍	❍	❍
My goals were clearly defined in the Simulink learning module. (4)	❍	❍	❍	❍	❍
I developed the ability to communicate clearly about the concept of using Simulink to program a robot (5)	❍	❍	❍	❍	❍
Using the Simulink learning module increased my productivity (6)	❍	❍	❍	❍	❍
I would visit this learning module as often as I can (7)	❍	❍	❍	❍	❍
Using the Simulink learning module improved my performance (8)	❍	❍	❍	❍	❍
I became more interested in the concept of using Simulink to program a robot (9)	❍	❍	❍	❍	❍

I knew clearly what I wanted to do in the Simulink learning module. (10)	❍	❍	❍	❍	❍
This was one of my favorite learning modules (11)	❍	❍	❍	❍	❍
In this Simulink learning module I learned how to identify various alternatives/solutions to a problem using the instructional materials (12)	❍	❍	❍	❍	❍
I was deeply engrossed in the Simulink learning module (13)	❍	❍	❍	❍	❍

Q13 Please rate the degree to which you agree with the following statements in this questionnaire by bubbling in or clicking on the response according to the following 5-point-scale

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I had fun working on this learning module (1)	❍	❍	❍	❍	❍
I know what I wanted to achieve in the Simulink learning module. (2)	❍	❍	❍	❍	❍
The instructional materials in this Simulink learning module improved my problem solving skills (3)	❍	❍	❍	❍	❍
Using the Simulink learning module enabled me to accomplish my tasks more quickly (4)	❍	❍	❍	❍	❍
I intend to link to this learning module when I am studying concepts that involve using Simulink to program a robot (5)	❍	❍	❍	❍	❍

I was stimulated to do additional work in the area of applications of using Simulink to program a robot (6)	❍	❍	❍	❍	❍
I found the Simulink learning module useful (7)	❍	❍	❍	❍	❍
In this Simulink learning module I learned how to inter-relate important topics and ideas using the instructional materials. (8)	❍	❍	❍	❍	❍
I was absorbed intensely in the Simulink learning module. (9)	❍	❍	❍	❍	❍
Using the Simulink learning module made it easier to do my work (10)	❍	❍	❍	❍	❍
I would stay longer on this learning module than others (11)	❍	❍	❍	❍	❍

I learned how to sort relevant from irrelevant facts using the instructional materials in this Simulink learning module. (12)	❍	❍	❍	❍	❍
I concentrated fully on the Simulink learning module (13)	❍	❍	❍	❍	❍
I had a strong sense of what I wanted to do in the Simulink learning module. (14)	❍	❍	❍	❍	❍
The learning module has been enjoyable (15)	❍	❍	❍	❍	❍
I gained a good understanding of the concept of using Simulink to program a robot (16)	❍	❍	❍	❍	❍
Using the Simulink learning module enhanced my effectiveness (17)	❍	❍	❍	❍	❍
I intend to prolong my staying on this learning module (18)	❍	❍	❍	❍	❍

Q14 Comments:

Robot Lab 1 Handout

Engr. 1110 Robot Loops and Squares **Spring 2014**

50 points

Divide into your Lab Teams. Change the team member at the keyboard at regular intervals so each team member operates the computer. If anyone did not get a turn at the keyboard last lab they will be first at the keyboard. Each team member is to submit a copy of the Simulink Models from the tasks to Canvas.

Task 1: 10 points

Create a model using the LEGO MINDSTORMS NXT and Stateflow libraries that drives the robot forward along a straight line for 5 feet and stops. You will need to adjust the power to the motors until the robot moves in a straight line.

Task 2: 10 points

Create a model using the LEGO MINDSTORMS NXT and Stateflow libraries that turns the robot 90° to the right about an axis passing vertically between the wheels.

Task 3: 30 points

Using your drive forward model and turn the robot 90° to the right model create a new model that commands the robot the drive in a square 5 feet long on a side. Each successfully completed drive 5ft and 90° turn to the right is worth 7.5 points.

A five point bonus will be awarded if the robot returns to the starting tile. A two point bonus will be awarded if the robot reaches one of the eight tiles surrounding the start tile. Place a marker on the starting square.

Each team will demonstrate the performance of their models to the instructors to receive the points for each task.

Robot Lab 1 Rubric

Group No:	Section:

Points	**10**	**7.5**	**5**	**2.5**	**0**
Task 1	Robot moves along a straight line for 5 feet and stops	Robot does not move on a straight line OR moves > or < 5 feet	Robot does not move on a straight line AND moves > or < 5 feet	The condition for transition from one state to another is wrong	No file turned in or Task not started
Task 2	Robot turns 90 to the right along an vertical axis in between both the wheels	Robot turns > or < 90 OR the axis of rotation is not the vertical axis in between both the wheels	Robot turns > or < 90 AND the axis of rotation is not the vertical axis in between both the wheels	The condition for transition from one state to another is wrong	No file turned in or Task not started
Points	**30**	**22.5**	**15**	**7.5**	**0**
Task 3	Robot completes a square 5 feet long and stops	Robot completes 3 sides of a square 5 feet long and stops	Robot completes 2 sides of a square 5 feet long and stops	Robot completes 1 side of a square 5 feet long and stops	No file turned in or Task not started
Points	**5**	**2**			
Bonus Points	Robot returns to the starting tile	robot reaches one of the eight tiles surrounding the start tile			

Robot Lab 1 Evaluation

TA Name:
Section number and type (control / Experimental):
Questions from students which is not explained in the tutor/ presentation

1.
2.
3.
4.
5.

Type of questions that students ask frequently (Write high or moderate or low against each type)

1. Logical
2. Basic (how to open file, save, run)
3. Operation of Robot (navigation within the CPU brick of Robot)
4. Simulink environment (connecting blocks, Zoom in/out, Copy)
5. Questions on chart (creating inputs outputs)

Time taken by each group to finish the entire task

Group	Start Time	Finish Time
1		
2		
3		
4		
5		

Comments on what difficulties students face

Robot Lab 1 Quiz

Name:
Group:
Section:

Each correct answer is awarded 1 credit. Total 5 points

Choose the correct option for questions from 1 to 4. Write one sentence for answering question 5

1. How many actuators are connected to the LEGO MINDSTORMS NXT robot?
    a. 0
    b. 1
    c. 2
    d. 3
2. What is the output of the Encoder after the LEGO MINDSTORMS NXT robot has travelled 2 feet? (approximate value)
    a. 625
    b. 1250
    c. 1875
    d. 3125
3. What is the minimum number of states required (within chart) for task 1?
    a. 0
    b. 1
    c. 2
    d. 3
4. What is the minimum number of sensor inputs required for performing task 3?
    a. 1
    b. 2
    c. 3
    d. 4
5. Write the format of the condition for transition from one state to another within chart block

Robot Lab 2 Handout

Robot 2 Sensors and Navigation 50 points Spring 2014

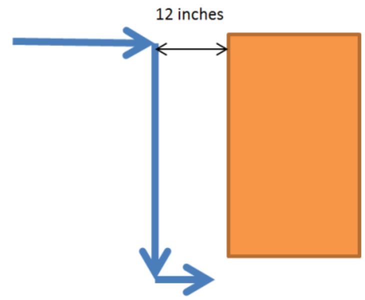
Divide into your Robot Teams. The lab is divided into three tasks for your team to complete with your robot.

Task 1: 10 points
Learning goal: Exploring the performance of digital devices sampling data from sensors.

Develop a model (program) that will drive the robot in a straight line and stop 12 inches from an obstacle using the ultrasonic sensor. The ultrasonic sensor looks like the robot's head with eyes on the cover picture. Mount the ultrasonic senor to the robot. You will need to convert the input to centimeters from inches in the model. Start with your travel 5ft model from the previous robot lab use the ultrasonic sensor instead of the motor encoder for control.

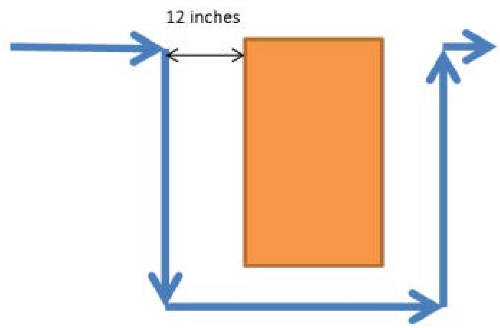
Task 2: 20 points
Learning goal: Using systematic task analysis for robot model planning.

Develop a model (program) that will drive the robot up to 12 inches from an obstacle of changeable width and depth, turn the robot, drive the robot up to the end of the obstacle, turn again and stop. The block represents the obstacle. The arrow represents the path of the robot.



Task 3: 20 points
Learning goal: Going from simple robot behaviors to complex behaviors by combining the models.

Use the models from task 1 and 2, create a program that will drive the robot forward while bypassing obstacles and returns to the original line of travel. A five point bonus will be awarded if the robot returns to the original line of travel. A two point bonus will be awarded if the robot returns to within one tile, 12 inches, of the starting line of travel.



Submit a copy of your model from Task 3 to Canvas.

Robot Lab 2 Rubric

Group No:	**Section:**

Points	**10**	**7.5**	**5**	**2.5**	**0**
Task 1	Robot moves along a straight line and stops 12 inches from an obstacle	Robot does not move on a straight line OR stops > or < 12 inches from an obstacle	Robot does not move on a straight line AND stops > or < 12 inches from an obstacle	The condition for transition from one state to another is wrong	No file turned in or Task not started
Points	**20**	**15**	**1**	**5**	**0**
Task 2	Robot Completes line 2 with near 90 degrees turn and turns again and stops.	Robot Completes line 2 with turn angles way off 90 degrees	Robot completes line 2 but does not turn after that. (goes on in a loop)	The condition for transition from one state to another is wrong. (the loop statement)	No file turned in or Task not started
Task 3	Robot bypasses obstacles and returns to the original line of travel	Robot completes the line 3 and 4 as shown in the figure but is not programmed to stop at the line of travel	Robot completes the line 3 as shown in the figure	Robot completes line 3 but does not turn after that. (goes on in a loop)	No file turned in or Task not started
Points	**5**	**2**			
Bonus Points	The robot returns to the original line of travel	The robot returns to within one tile, 12 inches, of the starting line of travel.			

Robot Lab 2 Evaluation

TA Name:
Section number and type (control / Experimental):
Questions from students which is not explained in the tutor/ presentation

1.
2.
3.
4.
5.

Type of questions that students ask frequently (Write high (>5) or moderate (2-5) or low (<2) against each type)

6. Logical
7. Basic (how to open file, save, run)
8. Operation of Robot (navigation within the CPU brick of Robot)
9. Simulink environment (connecting blocks, Zoom in/out, Copy)
10. Questions on chart (creating inputs outputs)

Time taken by each group to finish the entire task

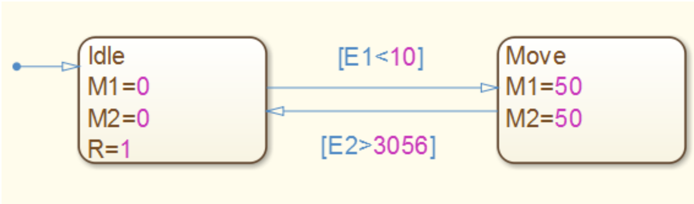
Group	Start Time	Finish Time
1		
2		
3		
4		
5		

Comments on what difficulties students face

Robot Lab 2 Quiz

Name:
Group:
Section:
Each correct answer is awarded 1 credit. Total 5 points
Choose the correct option for questions from 1 to 4. Write one sentence for answering question 5

1. What is the minimum number of states required for task 1?
    a. 1
    b. 2
    c. 3 without a reset value
    d. 3 with a reset value
2. What is the output of the Encoder after the LEGO MINDSTORMS NXT robot stops one foot in front of the obstacle? (approximate value)
    a. 625
    b. 1250
    c. 1875
    d. Depends on the start position
3. R is the external signal to Encoder E1 to reset the rotation value. What is the Value of R in state 'Move'?
    a. 0
    b. 1
    c. Either 0 or 1
    d. Not defined



4. What of the following requires the use of counter?
    a. Task 1
    b. Task 2
    c. Task 3
    d. Task 2 and 3
5. Write the format of the condition action in the transition label?

Appendix 3

Units Tutor

Units Tutor Script

SECTION 1

In this tutor you will be introduced to

- Importance of units
- Physical quantity and Dimension
- Units of measurement
- Rules for using SI Units and
- Unit Conversion

Importance of units

In science, when quantities are measured or calculated, they must be given proper units. A measurement without a unit specification really does not make much sense. Imagine if someone told you that Mt. Everest is 10,000 tall. Without a unit specification this number should mean nothing to you. We need standard units to be able to communicate facts, measurements, durations clearly and precisely.

SECTION 2

Physical Quantity

A physical quantity is a physical property of a body, or substance that can be quantified by measurement. [Joint Committee for Guides in Metrology (JCGM), International Vocabulary of Metrology, Basic and General Concepts and Associated Terms (VIM), III ed., Pavillon de Breteuil : JCGM 200:2012 (on-line)] A few examples include Temperature, Volume, Length, Mass, etc.

Dimensions

Dimensions are used to describe physical quantity. The Dimension of Mass is M, Length is L, Time is T, and electric Current is I and so on. Dimensions are divided into two categories – Fundamental and derived. A Fundamental Dimension is a dimension that can be usefully manipulated when expressing all physical quantities.

Derived dimensions are a combination of two or more fundamental dimension. For example, velocity is a derived dimension. Velocity is distance over time taken which can be written as a combination of length L and time T.

Dimensional System

This can be defined as a smallest number of fundamental dimensions that will form a consistent and complete set for a field of science. For example, Mass M, Length L and Time T can form a complete mechanical dimensional system because all other physical quantities can be expressed in terms of these three quantities. There are two dimensional systems. They are The Absolute system and the Gravitational System. The Absolute system is not affected by the gravity and its fundamental dimensions are length L, time T and mass M. The Gravitational system is affected by the gravity and its fundamental dimensions are length L, time T and Force F.

Now it's your turn

Units of measurement

How long is one foot? our feet may not be of same length. Whose feet do we use to measure? At one point, the length of a foot was the length of the king's foot, and that changed every time a new ruler was on the throne.

It is said that King Henry I of England, whose rule began in 1100, decided to standardize unit of length with his foot. Now imagine what happens after King Henry dies? Will his successor's foot be same length as his? Hence we need to have a standard that can be used anytime and anywhere. A unit of measurement is a definite magnitude of a physical quantity that is used as a standard for measurement. ["measurement unit", in International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM) (3rd ed.), Joint Committee for Guides in Metrology, 2008, pp. 6–7.] For example, length is a physical quantity. The meter is a unit of length that represents a definite predetermined length. When we say 10 meters, we actually mean 10 times the definite predetermined length called "meter". The International System of Units is intended to serve as an international standard that will provide worldwide consistency.

There are three fundamental systems of units that are used today. The metric system is the most widely used system in the world. It is based on the metre, kilogram and second (MKS) as the units of length, mass and time respectively. The two other systems of units are commonly used in the United States. They are U.S customary system and the Engineering System

This picture of World Map shows Metrication, color-coded by year of conversion. The United States is the only developed country that uses U.S Customary System.

Base Units

International System of Units, defines seven units of measure as a basic set from which all other SI units are derived. The SI base units and their physical quantities are:

- meter for length (US English: meter)
- kilogram for mass (note: not the gram)
- second for time
- ampere for electric current
- kelvin for temperature
- candela for luminous intensity
- mole for the amount of substance.

Derived Units

The International System of Units (SI) specifies a set of seven base units from which all other SI units of measurement are derived. Each of these other units (SI derived units) is either dimensionless or can be expressed as a product of (positive or negative, but usually integral) powers of one or more of the base units. For example, the SI derived unit of area is the square metre (m2), and the SI derived unit of density is the kilogram per cubic metre (kg/m3 or kg m-3). SI derived unit of velocity is meter per second, acceleration is meter per second square, force is kilogram meter per second square and so on.

SECTION 3

Rules for using SI units

SECTION 4

Unit Conversion

Let's have a look at a famous unit conversion error.

On September 23, 1999 NASA lost the $125 million Mars Climate Orbiter spacecraft after a 286-day journey to Mars. Miscalculations due to the use of English units instead of metric units apparently sent the craft slowly off course - 60 miles in all. Thrusters used to help point the spacecraft had, over the course of months, been fired incorrectly because data used to control the wheels were calculated in incorrect units. Calculations placed the orbiter at an altitude of 110 kilometers from mars surface; 80 kilometers is the minimum altitude that Mars Climate Orbiter was thought to be capable of surviving during this maneuver. Final calculations placed the spacecraft in a trajectory that would have taken the orbiter within 57 kilometers of the surface where the spacecraft likely disintegrated because of atmospheric stresses. The primary cause of this discrepancy was engineering error. Specifically, the flight system software on the Mars Climate Orbiter was written to take thrust instructions using the metric unit newtons (N), while the software on the ground that generated those instructions used the English System of Units pound-force (lbf).

How would you add 1 meter and 1 foot? You can never add them unless they are in the same units. So let us look at the procedure for converting a physical quantity from one unit to another.

The left hand side of the equation has three terms. Two on the numerator and one on the denominator. The first term on the numerator is the value what you have with its given unit. The second term on the numerator is the value A in the units you require and the term on the denominator is the value B in the given unit such that value of A in unit you want is equal to value of B in the given unit. The right hand side of the equation is what you require.

Let us look at an example. Assume that you need to convert 5.1 meters in centimeters. You are also given that 100 cm is equal to 1 m. The first term on the numerator on left hand side of the equation is 5.1 m. The second term on the numerator is 100 cm and the term on the denominator is 1 m. When we calculate the left hand side of the equation, we get 510 cm. m on the numerator cancels with the m on the denominator.

Units Quiz

Choose the correct answer. (1kg = 2.2lb)

1. Which is not a physical quantity?
    a. Force
    b. Second
    c. Temperature
    d. Density
2. Which following system depends on gravity?
    a. Absolute System
    b. Gravitational System
    c. Both
    d. None
3. Which is not a fundamental dimension?
    a. L
    b. M
    c. T
    d. F
4. Which of the following is not a derived dimension?
    a. Force
    b. Velocity
    c. Temperature
    d. Density
5. Which of the following is according to the rules for writing SI units?
    a. 44.4km
    b. 44.4 kilometers
    c. 44.4Km
    d. 44.4 K m
6. There are __ SI base units.
    a. 6
    b. 7
    c. 8
    d. 9
7. Which of the following is not a SI base unit?
    a. ft
    b. kg
    c. s
    d. K
8. Which is the most widely used fundamental system of units?
    a. US Customary System
    b. MKS system

c. Engineering System

d. CGS System

9. 1Kg + 1lb?

a. 2kg

b. 3.2kg

c. 1.45kg

d. 1.45lb

10. Convert 15 lb to kg

a. 6.8kg

b. 33.1kg

c. 32.1kg

d. 31.1kg

Units Tutor Survey

Q1 The Units, Dimensions and Conversions learning module includes materials covered during lecture and/or ActiveLearning Exercise (Introduction to Units, Dimensions and Conversions using a video/game-based exercise) in the lab.

Q2 Please enter the CODE provided by your lab instructor

Q3 Please select your lab section from the list below
- ❍ 13 (1)
- ❍ 14 (2)
- ❍ 15 (3)
- ❍ 20 (4)
- ❍ 21 (5)
- ❍ 31 (6)

Q4 Gender
- ❍ Male (1)
- ❍ Female (2)

Q6 Major
- ❍ Business or sub-discipline (1)
- ❍ Engineering or sub-discipline (2)
- ❍ Other (please list) (3) ____________________

Q7 Status
- ❍ Freshmen (1)
- ❍ Sophomore (2)
- ❍ Junior (3)
- ❍ Senior (4)
- ❍ Graduate Student (5)

Q8 Race
- ❍ White (1)
- ❍ African-American (2)
- ❍ Hispanic (3)
- ❍ Asian-American (4)
- ❍ American Indian (5)
- ❍ Other (6)

Q9 Did you have any previous knowledge about Units, Dimensions and Conversions?
- Yes (1)
- No (2)

Q10 Did you have any previous knowledge about rules for writing SI Units?
- Yes (1)
- No (2)

Q11 If you answered "yes" to the previous question, please list the course name where the topic was introduced.

Q12 Please rate the degree to which you agree with the following statements in this questionnaire by bubbling in or clicking on the response according to the following 5-point-scale

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
The instructional materials in the Units, Dimensions and Conversions learning module helped me identify logical tools that will assist me in decision-making (1)	❍	❍	❍	❍	❍
My attention was focused on the Units, Dimensions and Conversions learning module (2)	❍	❍	❍	❍	❍
I enjoyed many aspects of this learning module (3)	❍	❍	❍	❍	❍
My goals were clearly defined in the Units, Dimensions and Conversions learning module. (4)	❍	❍	❍	❍	❍
I developed the ability to communicate clearly about the concept of Units, Dimensions and Conversions (5)	❍	❍	❍	❍	❍
Using the Units, Dimensions and Conversions learning module increased my productivity (6)	❍	❍	❍	❍	❍
I would visit this learning module as often as I can (7)	❍	❍	❍	❍	❍
Using the Units, Dimensions and Conversions learning module improved my performance (8)	❍	❍	❍	❍	❍

I became more interested in the concept of Units, Dimensions and Conversions (9)	❍	❍	❍	❍	❍
I knew clearly what I wanted to do in the Units, Dimensions and Conversions learning module. (10)	❍	❍	❍	❍	❍
This was one of my favorite learning modules (11)	❍	❍	❍	❍	❍
In this Units, Dimensions and Conversions learning module I learned how to identify various alternatives/solutions to a problem using the instructional materials (12)	❍	❍	❍	❍	❍
I was deeply engrossed in the Units, Dimensions and Conversions learning module (13)	❍	❍	❍	❍	❍

Q13 Please rate the degree to which you agree with the following statements in this questionnaire by bubbling in or clicking on the response according to the following 5-point-scale

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I had fun working on this learning module (1)	❍	❍	❍	❍	❍
I know what I wanted to achieve in the Units, Dimensions and Conversions learning module. (2)	❍	❍	❍	❍	❍
The instructional materials in this Units, Dimensions and Conversions learning module improved my problem solving skills (3)	❍	❍	❍	❍	❍
Using the Units, Dimensions and Conversions learning module enabled me to accomplish my tasks more quickly (4)	❍	❍	❍	❍	❍

I intend to link to this learning module when I am studying concepts that involve Units, Dimensions and Conversions (5)	❍	❍	❍	❍	❍
I was stimulated to do additional work in the area of applications of Units, Dimensions and Conversions (6)	❍	❍	❍	❍	❍
I found the Units, Dimensions and Conversions learning module useful (7)	❍	❍	❍	❍	❍
In this Units, Dimensions and Conversions learning module I learned how to inter-relate important topics and ideas using the instructional materials. (8)	❍	❍	❍	❍	❍

I was absorbed intensely in the Units, Dimensions and Conversions learning module. (9)	❍	❍	❍	❍	❍
Using the Units, Dimensions and Conversions learning module made it easier to do my work (10)	❍	❍	❍	❍	❍
I would stay longer on this learning module than others (11)	❍	❍	❍	❍	❍
I learned how to sort relevant from irrelevant facts using the instructional materials in this Units, Dimensions and Conversions learning module. (12)	❍	❍	❍	❍	❍
I concentrated fully on the Units, Dimensions and Conversions learning module (13)	❍	❍	❍	❍	❍

I had a strong sense of what I wanted to do in the Units, Dimensions and Conversions learning module. (14)	❍	❍	❍	❍	❍
The learning module has been enjoyable (15)	❍	❍	❍	❍	❍
I gained a good understanding of the concept of Units, Dimensions and Conversions (16)	❍	❍	❍	❍	❍
Using the Units, Dimensions and Conversions learning module enhanced my effectiveness (17)	❍	❍	❍	❍	❍
I intend to prolong my staying on this learning module (18)	❍	❍	❍	❍	❍

Q14 Comments:

Appendix 4

Sample Question Papers of BSEN 3310 and BSEN 5220

[redacted]

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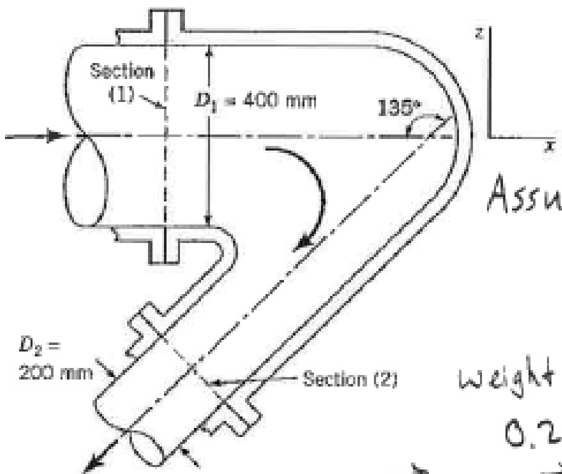
2011 BSEN 3310 FINAL EXAMS **Time: 2 hr 30min**

Name: **Good luck**

Question 1: A converging elbow turns water through an angle of 135 degrees in a vertical plane. The flow cross section diameter is 400 mm at the elbow inlet (section 1) and 200 mm at the elbow outlet (section 2). The elbow flow passage volume is 0.2 m^3 between sections 1 and 2. The water volume flowrate is 0.4 m^3/s and the elbow inlet and outlet pressures are 150 kPa and 100 kPa. The elbow mass is 10 kg. Calculate the anchoring forces required to hold the elbow in place. **(20 points)**



$V = 0.2\,m^3$

$\dot{V} = 0.4\,m^3/s$

Assume: 1) Steady flow

2) Assume T = 20°C

weight of the water

$0.2\,m^3 * 998.0\,kg/m^3 = 199.6\,kg$

$\sum \vec{F} = \sum_{out} \beta \dot{m} \vec{V} - \sum_{in} \beta \dot{m} \vec{V}$

$F_{Rx} + P_1A_1 - P_2A_2 = \beta \dot{m} V_2 \cos(45°) - \beta \dot{m} V_1$

$\dot{m} = \dot{V}\rho = (0.4\,m^3/s)(998\,kg/m^3) = 399.2\,kg/s$

$A_1 = 0.1256637\,m^2$

$A_2 = 0.0314159265\,m^2$

$V_1 = \frac{\dot{m}}{\rho A_1} = 3.183\,m/s$

$V_2 = \frac{\dot{m}}{\rho A_2}$ $12.73\,m/s$

$F_{Rx} = \beta \dot{m} V_2 \cos(45°) - \beta \dot{m} V_1 + P_2A_2 - P_1A_1$

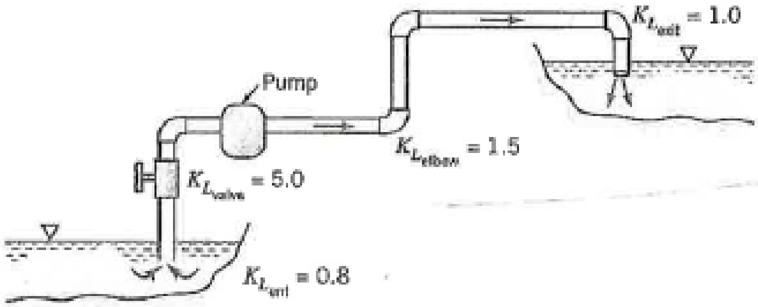
$F_{Rx} = 1.03(399.2\,kg/s)(12.73\,m/s)\cos(45°) - 1.03(399.2\,kg/s)(3.183\,m/s) + (100\,kPa)(0.0314159265\,m^2) - (150\,kPa)(0.1256637\,m^2)$

$F_{Rx} = 3701.2\,N - 1308.7\,N + 3141.6\,N - 18849.6\,N$

$F_{Rx} = -13{,}315.5\,N$

18

Questions 2: Determine the amount of electrical power consumed to pump water from the lower reservoir to the upper reservoir if the delivery rate is 152 L/s. The difference in elevation between the two reservoirs is 60 m, total pipe length is 150 m, pipe diameter is 20 cm and pipe roughness is 0.002 m. Assume the viscosity and density of water to be 0.000891 Pa·s and 1000 kg/m^3 respectively and the pump-motor efficiency to be 75%. **(20 points)**



Assume:
1) Steady & incompressible flow
2) Turbulent & fully developed flow

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1^{\nearrow 0} + h_{pump} = \frac{P_2}{\rho g} + \alpha_1 \frac{V_2^2}{2g} + z_2 + h_{turbine}^{\nearrow 0} + h_L$$

$V_1 = V_2$ so those terms cancel

$$\frac{P_1}{\rho g} + h_{pump} = \frac{P_2}{\rho g} + z_2 + h_L \qquad P_1 = P_{atm}$$

$$h_{pump} = \frac{P_{2,gage}}{\rho g} + z_2 + h_L$$

$\rho = 1000\ kg/m^3$

$g = 9.81\ m/s^2$

$z_2 = 60m$

$h_L = (f\frac{L}{D} + \sum K_L)\frac{V^2}{2g}$

$h_L = (f\ \frac{150m}{0.2m} + 8.3)\frac{(1.21 m/s)^2}{2(9.81 m/s^2)}$

$h_L =$

10/20

$\sum K_L = 8.3$

$V = \frac{\dot{V}}{A} = \frac{0.152\ m^3/s}{0.12566 m^2} = 1.21 m/s$

Assume: 1) 20°C

Question 3: A bus travels at 80 km/h in standard air. The frontal area of the vehicle is 10 m2 and the drag coefficient is 0.95. How much power is required to overcome aerodynamic drag? Estimate the maximum speed of the bus if the engine is rated at 450 hp. A young engineer proposes to add fairings on the front and rear of the bus to reduce drag coefficient. Tests indicate that this would reduce the drag coefficient to 0.85 without changing the frontal area. What would be the required power at 80 km/h and the new top speed? If the fuel cost for the bus is currently $200/day, how long would the modification take to pay for itself if it costs $4,000 to install?

a) $F_D = C_D A \frac{\rho V^2}{2} = (0.95)(10\,m^2)\left(\frac{1.204\,kg/m^3 \times (80\,km/hr)^2}{2}\right)\left|\frac{1\,m/s}{3.6\,km/hr}\right|^2\left|\frac{1\,N}{1\,kg \cdot m/s^2}\right|$

$F_D = 2824.19\,N$

$Power_D = F_D * V = (2824.19\,N)(22.22\,m/s)\left|\frac{1\,hp}{745.7\,W}\right| = 84.2\,hp$

b)

c) $F_D = (0.85)(10\,m^2)\left(\frac{1.204\,kg/m^3 \times (80\,km/hr)^2}{2}\right)\left|\frac{1\,m/s}{3.6\,km/hr}\right|^2\left|\frac{1\,N}{1\,kg \cdot m/s^2}\right|$

$F_D = 2526.9\,N$

$Power_D = F_D * V = 75.3\,hp$

d)

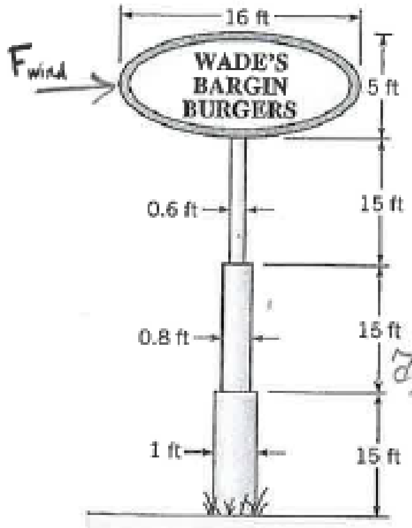
e) $\frac{84.2 - 75.3}{450} = 1.9771\%$ fuel savings

15,817 days of operation

Assume 20°C

Question 4: The structure shown below consists of three cylindrical support posts to which an elliptical flat-sign is attached. Estimate the drag (Force) on the structure when a 50 mph wind blows against it. What is the resultant moment of the drag (Force) on at the base of the structure? **(20 points).** * Assume wind blows directly into the side of the sign

Assume turbulent flow



$A_{pole} = 15ft(0.6ft + 0.8ft + 1ft) = 36ft^2$

$A_{sign} = \pi\left(\frac{5^2}{4}\right) = 19.6349\ ft^2$

$C_{D_{pole}} = 1.9 \qquad C_{D_{sign}} = 0.175$

a) $F_D = C_D A \frac{\rho V^2}{2}$

$F_D = A\frac{\rho V^2}{2}(C_{D_{pole}} + C_{D_{sign}})$

$F_D = (55.6349\ ft^2)\left(\frac{0.07518\ lbm/ft^3 * (50mph)^2}{2}\right)(1.9 + 0.175)\left|\frac{1.46667 ft/s}{1\ mph}\right|^2$

$F_D = 23336.87\ lbm \cdot ft/s^2 * \left|\frac{1\ lbf}{32.174\ lbm\ ft/s^2}\right|$

$\boxed{F_D \approx 725.333\ lbf}$

b) $M_R = F_D * L$ not the same

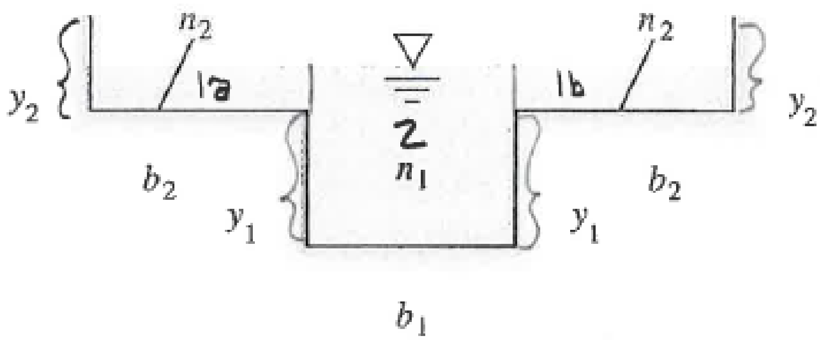
Assume $L = 3/4$ total Length

$M_R = 725.333\ lbf * 3/4(50ft)$

$\boxed{M_R = 27200\ lbf \cdot ft}$

12/20

Question 5: A natural channel often consists of a deep main channel plus two flood plains as shown below. If the channel has the same slope everywhere, estimate the discharge in m^3/s if $y_1 = 6$ m, $y_2 = 2$m, $b_1 = 15$ m, $b_2 = 35$ m, $n_1 = 0.020$, and $n_2 = 0.040$ with a slope of 0.0002. What is the effective 'n' for the channel? **(20 points)**



Subsection 1

1a + 1b

$A_{c_1} = 2m \times 35m + 2m \times 35m = 140m^2$

$P_1 = 74$ m

$R_{h1} = \frac{140\ m^2}{74m} = 1.89189$ m

Subsection 2

$A_{c2} = 8m \times 15m = 120m^2$

$P_2 = 27m$

$R_{h2} = \frac{120m^2}{27m} = 4.444m$

Total

$A_c = 260\ m^2$ $\quad p = 101m \quad R_h = \frac{A_c}{P} = \frac{260\ m^2}{101m} = 2.574m$

a) $\dot{V} = \dot{V}_1 + \dot{V}_2 = \frac{a}{n_2} A_{c1} R_{h_1}^{2/3} S_o^{1/2} + \frac{a}{n_1} A_{c2} R_{h_1} S_o^{1/2}$

$\dot{V} = (1 m^{1/3}/s)\left[\frac{(140m^2)(1.89189m)^{2/3}}{0.040} + \frac{(120m^2)(4.444m)^{2/3}}{0.020}\right](0.0002)^{1/2}$

$\dot{V} = 305.07 m^3/s$

b) $n_{eff} = \frac{a A_c R_h^{2/3} S_o^{1/2}}{\dot{V}} = \frac{(1 m^{1/3}/s)(260m^2)(2.574m)^{2/3}(0.0002)^{1/2}}{305.07 m^3/s}$

$n_{eff} = 0.0226$

20

Overall grade 73.9/100

69/100

Lab exam

3.4/100

Name: [redacted]

BSEN 5220/6220
Mid-Term Exam
Spring 2011

This is a **closed book** exam. Place your answers in the space provided. If you need more space, write on the back of the pages. **The total number of points is 100. Total Time Allowed: 50 min + 10 min extra if you need it.**

1. **What is remote sensing? Explain the principle behind remote sensing systems (i.e., what kind of energy they use? what do they measure? etc.). [1+2 = 3 points]**

Remote sensing is the observation of objects/phenomenons ect. without actually being near it by using remote sensors

Electromagnetic energy

· Measures weather

2. **Which three things can a GPS system measure? Write the names of GPS segments? [3+3 = 6 points]**

1. latitude
2. longitude
3. elevation

position
time
velocity

-2

- Control
- Space - NASA/AR
- User

3. **If you are interested in obtaining the current status of GPS satellites, how would you go about finding it (i.e., what is the source of this information?)? [2 points]**

Found in Almanac and ephemeris data

✓

4. **The new civilian GPS signal already being transmitted on newer GPS satellites is on which carrier frequency? What is the name of this new civilian signal? What is the name of new carrier frequency designed for military and aerospace navigational application? What is the name of another civilian GPS signal that is planned for future [1.5+1.5+1.5 +1.5 = 6 points]**

- L2 ✓
- L2C - CNAV ✓
- L1IIR ✗ L5
- L5

4.0, 1.5

5. **List the names of two ground-based navigation systems. In general, higher frequency gives higher accuracy; then, why we do not use high frequency for ground-based systems? [2+2 = 4 points]**

CORS
USGS Coast Guard Beacon ✗ -2

High frequency punches through ionosphere
Low frequency refracts off of ionosphere ✓

6. **Explain why dual frequency receivers are able to reduce ionospheric error but not tropospheric error? Which parameter do you set in your GPS receiver to limit ionoshperic and troposheric errors? [3+1 = 4 points]**

L1 + L2 travel times are compared to determine reduction rate ionosphere where signals can still "bounce around"

Tropospheric error is due to water vapor

• SNR - signal to noise ratio

-0.5

elev mask

-1

7. **To have low HDOP, the satellites your receiver sees should be spread apart in space (ideally in four different quadrants). To have low VDOP, where do your satellites need to be? Is PDOP predictable? If so, how? [2+1+3 = 6 points]**

Satellites should be overhead receiver.

PDOP is predictable.

You can set the receiver to pick which satellites to use.

If they are far apart there is low error.

" " close together " " high error.

8. **Carrier phase positioning can provide you highly accurate position and elevation data. However, it requires resolution of carrier phase ambiguity. What is carrier phase ambiguity? How do some GPS receivers resolve this ambiguity? [3+4 = 7 points]**

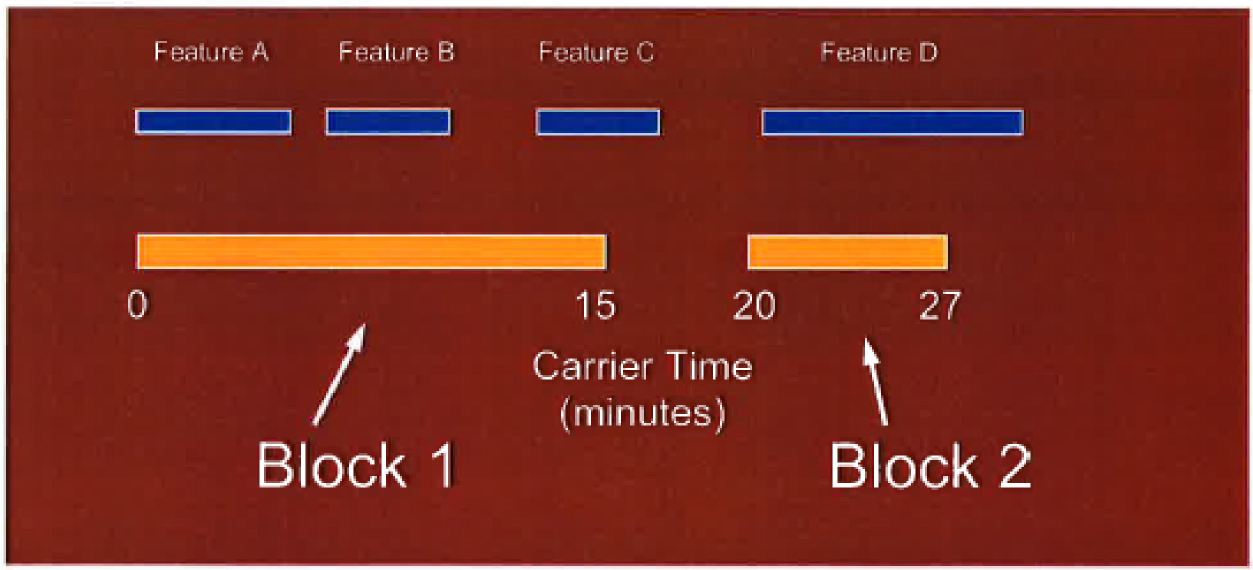
Ambiguity is uncertainty in measuring time for wavelength.

Ambiguity can be determined by applying the Doppler Shift concept.

not very clear

/3

9. **The figure below shows two carrier time blocks in minutes for the Trimble Geo3 receiver, which requires 10 min to resolve carrier-phase ambiguity. You collected four features A, B, C, and D in these two carrier time blocks. You use Pathfinder Office to differentially correct your data. While correcting these features, you selected carrier-phase only correction option (i.e., post-process in carrier phase only). What can you say about how these features will be corrected by the Pathfinder Office software? [5 points]**



Only Features A + B will be corrected with carrier phase data
C + D have insufficient segment lengths.

C partially corrected

-1

10. **A number of real-time GPS correction services were discussed in the class. Write names of three real-time correction services currently in use? [4.5 points]**

WAAS
CORS
USGS Coast Guard Beacon

Omnistar
Deere

11. **Two manufacturers use different reporting methods to report position accuracies achieved by their receivers. The first manufacturer has quoted accuracy of 3 meters (rms_2), while the second manufacturer has quoted accuracy of 2 meters (CEP). Receiver from which manufacturer is more accurate? Why (show through calculation)? Use the table below for conversion factor. [2+5 = 7 points]**

CEP =	rms_1 =	rms_2 =	67% =	95% =	68% =	98% =	
1	0.85	1.19	1.26	2.08	1.28	2.37	*CEP
1.18	1	1.41	1.49	2.45	1.51	2.80	*rms_1
0.84	0.71	1	1.06	1.74	1.07	1.99	*rms_2
0.79	0.67	0.95	1	1.64	1.01	1.88	*67%
0.48	0.41	0.58	0.61	1	0.62	1.14	*95%
0.78	0.66	0.93	0.99	1.62	1	1.85	*68%
0.42	0.36	0.50	0.53	0.88	0.54	1	*98%

▲ TABLE 1 Accuracy measures for circular, Gaussian, error distributions

1st manufacturer

CEP has 50% error rms 2: 39% error

2(0.5) = 1m 3(0.39) = 1.17m

-1

12. **GPS receiver manufacturer specifications also list NMEA messages used by the GPS receiver. What is the significance of NMEA messages? Which NMEA standard is applicable for GPS receivers? The NMEA sentence shown below contains position information as latitude and longitude. Write the latitude and longitude contained in this sentence. Convert the latitude and longitude in degrees, minutes, and seconds. [2+2+3+4 = 11 points]**

$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47

NMEA set standards for electronic signal data and sentence format.

NMEA 0183

123519 4807.038 N

01131.000 E

+ 4

13. **What is the difference between a geoid and an ellipsoid? What is the difference between HAE and elevation? Name any 3 datums presented in class. [2+2+3 = 7 points]**

Ellipsoid - smooth 3D ellipse

Geoid - rugged, complex 3D figure

HAE references ellipsoid

Elevation references geoid

NAD1927

NAD1983

Bermuda 1957

14. **What is a projection? Why do we use a projected coordinate system? Which properties can be distorted by projected coordinate systems? [2+2+4 = 8 points]**

- projection - 3D object represented in 2D
- to identify locations in mathmatical terms
- shape, area, distance, direction

-1

15. **I downloaded two GIS datasets for Lee County, Alabama from a GIS data clearing house on the internet. One of my dataset is in UTM Zone 16N and another one is in State Plane of Alabama East Zone. The datum for both the dataset is same. You pulled both of these datasets in a GIS software (say ArcMap), but they don't line up (don't appear to be at the same location). Give reasons why the datasets don't line up. You need to give me at least three reasons. I am looking for a specific answer. [5.5 points]**

1. Correct ArcMap datum is not being applied
2. Different projections are being used: UTM vs. Lambert Conformal Conic
3. Using different parallels

-4

16. **As the basis of State Plane Coordinate System, why do we use Lambert Conformal Conic projection for Tennessee and UTM projection for Alabama? What do X and Y coordinates in UTM projection called? What is a State Plane Coordinate System? [3+2+4 = 9 points]**

- Lambert is most accurate for distances running East-West
- UTM is most accurate for distances running North-South
- Easting + Northing
- highly accurate coord. system using multiple projections

17. **Before you start using a GIS dataset in ArcGIS, which four things are essential for you to know about the data (Hint: one of those things is coordinate system)? How would you go about finding this information? [3+2 = 5 points]**

Coord. system
Range code signals
Almanac
~~Data Dictionary~~ Atmospheric Data
Use ArcCatalog, look at metadata ?