Northeastern University

College of Arts and Sciences

Department of English/Advanced Writing in the Disciplines

An Active Learning Approach to Engineering Design using LEGO® Mindstorms Robots

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Prof. Susan Freeman
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Dear Professor Freeman,

As a mechanical engineer, I remember taking my first true major course requirement. Engineering Design is a very important course for first years because it gives students their first taste of the engineering major. However, this course is not utilized to full potential because it is not taught through the best possible means. The current course does an excellent job of conveying the ideas and knowledge to students, but it does so in a passive way. This limits the experience that students can take away from such an important course. A course that is built around group problem solving and critical thinking would greatly increase the skills that first year students will gain.

This proposal includes the research supporting a change to an active learning course and also has an appendix that gives example material, a course outline and project assignments for a prototype course. The information for this proposal was gathered through research and interviews with Professor Goldthwaite and Professor Jaeger. One of the many objectives of the proposal is to explain and define different types of conventional and active learning. Once defined, this proposal shows the research that has proven active learning is a more academically beneficial approach then conventional learning. Active learning has many methods; the chosen tool for the prototype course is LEGO® Mindstorms robotic construction kits.

The LEGO® Mindstorms robots are perfect for teaching the engineering process. The students will have to design, build, program and test their robots to reach a certain objective. LEGO® Mindstorms have infinite possibilities for engineer applications that can cover almost every major topic in engineering. The door is left open for students to explore and create with total control over their ideas. This is the perfect technique for an innovative school such a Northeastern which prides itself in teaching through experience. This does not have to be a final idea for Engineering Design; I am willing to help this project progress and participate as much as possible in the application of a prototype course. Thank you for your attention to this matter. If you have any questions or concerns, you can reach me at my office phone: 978-621-3773 or by e-mail: Sivak.se@neu.edu.

Sincerely,

Seth Sivak

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Executive Summary

First year engineering students at Northeastern University must all take a required Engineering Design course. This course is provided so that the students can have a firm idea of the engineering process and be introduced to several applications and examples of good engineering design. Engineering Design is especially important because it is the first experience students are given in the engineering major. The course is currently taught through a conventional lecture based method. This method works well for the course; however, it is not taught to full potential. Through an active learning approach the course will increase retention rate, knowledge comprehension, teamwork and critical thinking.

This active learning course could be implemented as a prototype in order to test the validity of these claims. Through research it has been proven that an active learning approach, even with very small changes to a traditional lecture, can have a profound effect on student understanding. Active learning is not utilized often in most universities. Northeastern University has always been known to have a unique style of education, focused on teaching through hands on experience. This makes Northeastern University the perfect candidate for an active learning course and the College of Engineering seems to be particularly suited for such a learning style.

There are many different methods of active teaching and learning. The prototype Engineering Design course should be taught using LEGO® Mindstorms robotic construction kits. These robots are very versatile and can be used in any number of problem solving and critical thinking applications that cover almost all engineering topics. Students will have to design, build, program and test their robots. All of these skills are vital for engineers and are best learned through experience. By giving groups of students different problems focusing on individual aspects of the engineering process, the students will gain experience that goes beyond simple design.

This prototype course could be executed through several different means. Appendix [1] of this proposal provides one possible method to create an active learning course. This appendix includes a syllabus, outline, projects, and example material. The provided material has been tailored to the current course objectives as much as possible. The main recommendation of this proposal is to add a LEGO® Lab section to the current Engineering Design course. This LEGO ® Lab will give students a chance to solve problems in small groups in a professional atmosphere. Appendix [1] contains the projects that have been created for the LEGO® Lab and also include how they can be assessed.

This prototype course is based on problem solving in a group atmosphere with the emphasis being hands-on experience. Northeastern prides itself on learning through professional experience. Many students choose to attend Northeastern based solely on the fact that at Northeastern they will receive an education unlike any other. Offering students a chance to actively engage in their own learning process will help carry on Northeastern's legacy of "Higher Learning. Richer Experience."

Section 1: Introduction

A first year engineering student stares up at the clock anticipating that his class is almost over for the day. He peers over at the professor who is writing some information on the board and explaining to the class what the homework will be for the next week. The *Engineering by Design* textbook lays casually open on the table in front of him; it is not even on the right page. He stopped taking notes about half way through the lecture so his notebook sits half-full with his pencil down on top of it. The student regains his focus long enough to write down the homework and the information about the upcoming design project. He is still frustrated from the last group project where he was stuck with writing up the paper when he really wanted to be doing the design. The class finally ends and the young student gathers his books and trudges back to his dorm room.

Not every student has this experience in Engineering Design, which is a mandatory course taken by all first year engineering students at Northeastern University. The course is taught by using conventional lectures to convey information to students. These lectures are augmented with an AutoCAD lab that meets once a week in a computer lab. The backbone of the course is the major and minor design projects that allow students to discover engineering and the many different disciplines therein. In order to increase retention rates, attitudes, problem solving and critical thinking, the College of Engineering should introduce a prototype Engineering Design course that utilizes active learning and LEGO® Mindstorms robotic construction kits.

Engineering Design is an integral part of the curriculum because it gives students their first experience in college level engineering. Therefore, it should be engaging as well as educational. The Engineering Design course is particularly conducive to a more active learning approach; that can convey all the necessary topics of the course and also give students a chance to improve their teamwork, critical thinking skills, and creativity. Research here demonstrates that active learning leads to better student attitudes and improvements in students' thinking and writing [1]. One of the most popular tools for active learning is LEGO® Mindstorms robotic construction kit.

These kits are used in conjunction with software that allows students to learn basic design principles as well as basic programming and computer science. Typically, this form of active learning is taught using team-oriented projects in which the students are given a problem to solve and then allowed to see the project through from start to finish. It has been proven that student involvement in learning is one of the most important predictors of success at the college level [1].

Section 2: Background

In order to compare the current Engineering Design course with an active learning prototype course it is important to define and understand the different styles of learning. Conventional learning, which is currently used in Engineering Design, is very broad in definition and is probably the most practiced way of teaching at the university level.

Active learning has several different techniques; cooperative learning, collaborative learning and problem based learning. Each of these methods requires an in-depth definition to explain the differences in theory and execution. This prototype course is designed to be used with LEGO® Mindstorms robots, therefore a description of what goes into a robot and how they are programmed is included. Further, this section provides the history of the LEGO® Company and describes how the LEGO® Mindstorms robotic construction kits are used in education.

2.1 Types of Learning

Educational techniques are as varied as subjects and students. In order to compare educational methods a base needs to be setup upon which all techniques can be judged. This section will give the basic theory of each type of learning described in this proposal. The definitions are broad in order to incorporate the many subtle differences involved in each style of learning and teaching. These characterizations only provide the theory of each learning style and list a few examples of how the theory can be executed. It is important to note that many courses utilize several techniques to convey information. This proposal will utilize a combination of different styles to reach as many students as possible.

2.1.1 Conventional Learning

Conventional learning is defined as an individual education experience in which the student is not directly involved in the learning process [1]. In undergraduate courses this method is typically demonstrated through lectures given by professors that instruct the individual student directly. Customarily, the assessment for this type of learning is formal exams. This style of learning is most often used in liberal arts courses where information is conveyed more through reading than through the use of examples or problems. An American History class, for example, can not easily be taught through group problem solving. It would be very difficult to formulate a set of problems for students to solve that would effectively teach American History better than a formal lecture where the information is presented.

However, conventional learning is not limited to lecture based teaching. Essentially, any course where the students are being taught rather than having an active role in teaching themselves is considered conventional learning. This style of teaching has proven to be an effective technique for many students because it usually follows a logical path through a textbook, which can be easy to follow. The problem arises with the students being able to concentrate on the lecture. The average student attention span is about fifteen to twenty minutes [1]. Research has shown that students remember about seventy percent of the information covered in the first ten minutes of a forty five minute lecture and only about twenty percent of the information presented in the last ten minutes [1]. This drop in data retention creates a significant problem for lecture based courses.

2.1.2 Active Learning

There are several types of active learning being used in education today. The term "active learning" is generally described as any form of instruction that engages students in the learning process [1]. Essentially, active learning demands that students participate in meaningful learning activities in order to understand why they are learning each specific topic. This definition is so broad that it could potentially include conventional techniques such as homework. However, active learning is most often seen in the activities done in the classroom. Active learning can be broken down into its common techniques: collaborative learning, cooperative learning, and problem-based learning.

Collaborative learning is usually described as an instructional method where groups of students work together towards a common goal [1]. This can encompass almost all group-based learning where students in a given group are assessed as a group. This style of learning is very similar to cooperative learning where students also work together in groups to solve a common problem. The difference is that in cooperative learning the students are working in groups but are assessed as individuals.

Cooperative learning assessments usually judge students on five specific aspects: individual accountability, mutual interdependence, face-to-face interaction, interpersonal skills, and teamwork [1]. Typically, cooperative learning incentives are given to promote learning through cooperation rather than competition.

Problem-based learning (PBL) is also considered a type of active learning**.** This style of learning is defined as any educational method where problems are given at the start of a learning cycle and through solving them the students learn the required material. Problem-based learning often encompasses parts of cooperative and collaborative learning [1]. The highlight of PBL is that it teaches the specified topic and many other common skills such as teamwork, communication, and critical thinking.

2.2 The LEGO® Company and Education

The LEGO® Company has been making toys for over half a century. Their philosophy has always been that "play is the essential ingredient in a child's growth and development. It grows the human spirit. It encourages imagination, conceptual thinking and creation" [2]. This philosophy now incorporates children of all ages. With many new products being geared towards older "children" the ideals set forth in the philosophy are starting to take on an educational tone. LEGO® created an Educational Division to help teachers and students realize the full potential of learning through LEGO® products. LEGO® has become an international vehicle of teaching on many levels and will expand more into the future [2].

2.2.1 The History of the LEGO® Company

In Billund, Denmark, Ole Kirk Christiansen and his son Godfred founded the LEGO® Company in 1932. Christiansen was a master carpenter who specialized in making ladders, ironing boards and wooden toys. The wooden toys became the most popular item sold by Ole and his son, and in 1934 they created the name LEGO® from "leg" and "godt," which means "play well" in Danish. As the first Danish company to buy an injection molding machine, LEGO® started to produce plastic bricks in 1949. LEGO® bricks were released internationally in 1969 and are now one of the most popular toys in the world [2].

2.2.2 LEGO® Educational Division

The LEGO® Company provides many resources for every level of education from pre-school to high school [2]. The LEGO® Educational Division provides a plethora of information on how to use LEGO® toys in an educational way. This division is "dedicated to the field of teaching and learning. LEGO® Educational Division develops learning concepts that inspire students to use their creativity and innate curiosity through experiencing things [for] themselves" [2]. An integral resource of the educational division is the activity databank which is geared towards younger students and has lists of possible ways to educate through LEGO® toys. In an effort to effectively integrate LEGO® products into the curriculum, the Educational Division attempts to create material relevant for every science and computer-related subject [2]. The LEGO® Educational division also provides a Quick Start Guide for LEGO® Mindstorms which contains a vast number of labs that introduce students to robotics concepts. The goal of the Quick Start Guide to LEGO® Mindstorms is to introduce students to the basic principles of robotics by doing basic labs that only take a few hours. While most of the Educational Division's material is free on the LEGO® website [2], they also provide much more thorough and specific teaching and project guides through authorized retailers.

2.3 LEGO® Mindstorms Robotics

A LEGO® Mindstorms robot is made up of many different components all necessary for the robot's success. This includes the physical construction of the robot and the behavioral programming given to the robot to complete certain tasks. The robot is made up of a microcomputer, input components and output components. The microcomputer will take the data from the input components, run it through the behavioral programming and send the proper data to the output components. This is a very simplified description of a robot; in fact these robots can be very complicated and diverse. Since the Mindstorms robots offer such an open ended platform they are ideal to let students explore their own creativity and individualism.

2.3.1 Anatomy of a LEGO® Mindstorms Robot

The basic LEGO® Mindstorms construction kit includes the RCX™ Microcomputer, CD-ROM containing software, 717 LEGO® elements, two LEGO® motors, two LEGO® touch sensors, and one LEGO® light sensor. The RCX™ Microcomputer is the brain inside any LEGO® Mindstorms robot. This microcomputer has the ability to store preprogrammed behaviors and sets of tasks that the robot can access to help achieve a given goal. The RCX™ also is the processing center for all the incoming data via the input sensors, which it then converts into instructions carried out by the output devices. A picture of the RCX™ can be viewed in Figure [1].

Figure [1]: The RCX™ Microcomputer [2]

The microcomputer uses the preprogrammed behavior to make decisions on given stimuli. The input ports use sensors that detect touch, light and temperature, and are shown in Figure [2].

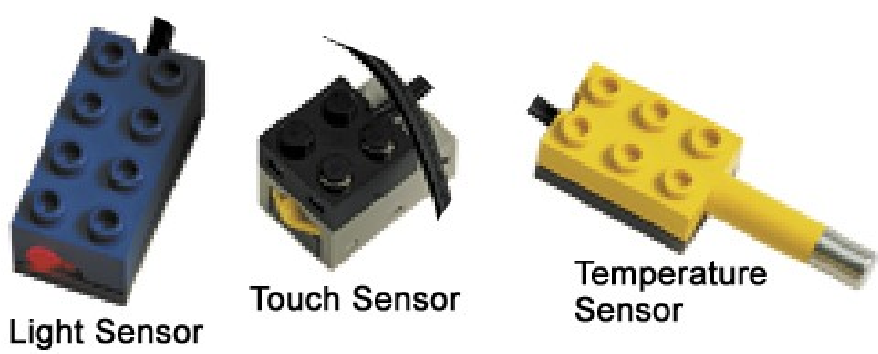

Figure [2]: The Input Components [2]

From the data provided by the input sensors, the microcomputer accesses the possible behaviors and chooses the correct one for the given situation. Usually the behavior of the robot needs to be changed by one or more of the output components. Output components such as motors or lamps are used to change the robots environment, Figure [3].

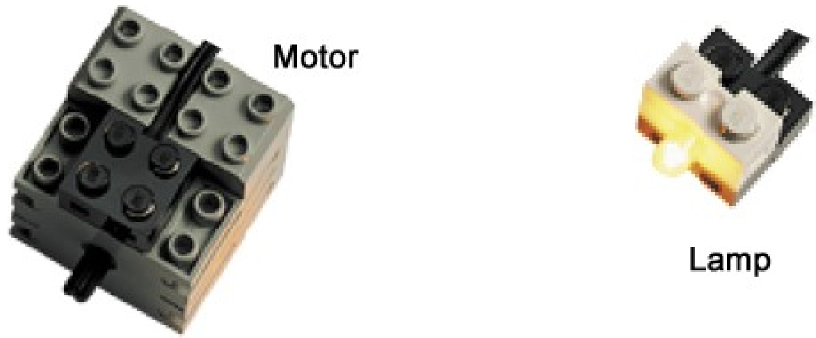

Figure [3]: The Output Components [2]

By programming the microcomputer with a set of behaviors for each change in environment, the robot is able to take sensory input and change its behavior accordingly. This is a very basic form of artificial intelligence and the simplest way to control a LEGO ® Mindstorms robot. The artificial intelligence becomes much more complicated when multiple robots are networked into a team and must work together to obtain a certain goal.

2.3.2 Programming LEGO® Mindstorms Robots

In order for the robot to function properly, it needs to be programmed with a set of behaviors. Included with the LEGO® Mindstorms package is a very simple graphics based programming tool using RCX Code. This programming language is geared towards a younger audience and is very limited in higher function programming. There are many different programming environments offered for LEGO® Mindstorms, and they cover every major operating system and programming language.

The first ever open source operating system (OS) for LEGO® Mindstorms robots is called BrickOS [3]. The idea behind having an open source platform is to create a common operating system that many developers can create programs for. The developers in this case are the students that use the platform to create programs for their robots. This operating system replaces the standard RCX Microcomputer OS, and it allows the user to write programs for the robot in the C or C++ programming language. This is valuable because Northeastern Engineering students will be required to learn C and C++ in a course given their first year.

Since this OS is open source there is a huge community of developers that constantly update it, and it is free to download and use. The website offers a large amount of example work and even holds design contests each month. This community is a great way for students to network with other Mindstorms programmers and also provides inspiration for possible solutions to the assigned problems. The entire BrickOS package includes the OS for the RCX, the utilities to install programs to the RCX, sample programs and tutorials. This OS operates on any Linux machine and also on Windows. The diversity of this program allows quick integration of the software at essentially no cost.

Section 3: Problem Description

Engineering Design is a mandatory course for all first year engineering students. This course provides students with insight into all the different disciplines inside engineering and also the engineering design process. Since this course is the introductory engineering course for first year students it has an obligation to inspire and challenge the students. The current course does not take advantage of active learning techniques that could help increase students knowledge comprehension, retention, problem solving and creativity. This section will outline some of parts of the course that could be improved and also explain why changes to this course would be beneficial.

3.1 Educational Theory

The Engineering Design course is taught primarily through lectures. Most homework and AutoCAD assignments are done by single students. The main projects are completed in small groups that are self directed by the students with help of the professor. This would categorize the class as being taught through a combination of conventional learning, collaborative learning and problem based learning. Research has shown that small changes in the way this course is taught will lead to an improvement in short and long term retention as well as study for understanding rather than simple recall [1].

3.1.1 The Conventional Lecture

The lectures used in the current course last about sixty to sixty five minutes. As shown previously, the average student can only concentrate for about fifteen to twenty minutes. Also, students tend to remember less as the lecture continues. Many educational theorists believe that if students are given breaks or a chance to start fresh a few times during the lecture the students retain more knowledge [1]. However, this problem is also apparent in other forms of inactive learning, such as watching a movie. Movies are used in the Engineering Design course to help teach students the engineering design process and also cover the area of engineering failure.

A study done by Ruhl et al. [4] has shown that small differences can drastically change a lecture based class. Seventy two students in two courses were taught using a forty five minute lecture. This lecture was broken up three times by two minute breaks (about once every fifteen minutes). During these two minute breaks students were told to get together with a partner and clarify their notes. In parallel to this, another set of students was taught the same course without breaks in the lecture, and the two groups were compared on short and long term knowledge retention. The short term retention was tested by administering a free-recall exercise where students listed everything they learned in the lecture immediately following its completion. This exercise was scored by the number of facts the students could list correctly in three minutes. The students that were given the break during the lecture scored an average of 108 correct answers, while the students with a straight lecture only averaged 80. The long term retention was tested using a sixty five question multiple choice exam given one and half weeks after the last lecture. The first class scored an average of 89.4 for students given breaks during the lecture and 80.9 for the students without the breaks. Similarly, the second class scored an average of 80.4 for students with the break procedure and 72.6 for the students not given any breaks. The effectiveness of giving even a simple pause during a lecture can greatly enhance the students understanding and retention of knowledge.

3.1.2 Competitive Learning

The homework and AutoCAD assignments given to single students are a characteristic of competitive learning. Competitive learning is the opposite of collaborative learning, where students work together to help better understanding. Several studies have shown how collaborative learning (students working on assignments in small groups) is a more effective way of teaching. A study done by Springer et al. [5] showed that a student working competitively would score an average of a 75 on a test, while students working together throughout the course would score an 81. This data was taken from combining thirty seven studies of students in science, mathematics, engineering and technology. However, students subjected to constant or only group work had only a slight increase in knowledge understanding and retention. This means that an essential mix of collaborative and competitive activities is needed to achieve the best results.

3.1.3 Problem Based Learning in Small Groups

The projects in Engineering Design involve problem solving within small groups. These small groups are either given a problem to solve, or told to find a problem of interest and then solve it. The nature of these groups can cause a problem for some students that are not very experienced with group work. Research into problem based group learning has shown what sort of groups work most effectively. Research performed by Norman and Schmidt [6] characterized the different types of group dynamics and how effective they can be. The results of this analysis are shown in Table [1].

Table [1]: Academic Achievement Associated with Group Dynamics in PBL [6]

Characteristic	Effect Size
Individualized	0.23
Cooperative	0.54
Small group	0.31
With non-expert tutors	-0.074
Self-paced	-0.07
Self-directed	-0.05
Using problems	0.20
Inquiry Based	0.16
Instruction in problem solving	0.54
Inductive	0.06

The data is given in effect size. An effect size is defined as the difference between means of a subject and control population divided by the pooled standard deviation of the populations [1]. In other words, if an effect size improvement of 1 is found it would mean that the test population out performed the constant population by one standard deviation [1]. The purpose of this table is to show how the group dynamic can greatly change the overall effectiveness of problem based learning.

The group dynamics of the students in Engineering Design would most likely fall into some of the negative characteristics. The groups are usually self-directed and self-paced with no tutors. The students are given a strict set of assignments that typically build on each other towards the final goal. If the professor takes an active part in directing the group it will greatly increase the groups' academic achievement.

3.2 Learning with LEGO® Mindstorms

Northeastern University's motto of "Higher Learning. Richer Experience" is a doctrine that the school was built on. The idea of learning through experience is incorporated into every student's curriculum with the inclusion of the Cooperative Education Program. However, this does not have to be the only way students gain knowledge through hands on experience. Active learning courses using LEGO® Mindstorms are currently being used in many undergraduate universities all over the world [7,8,9]. These courses are typically first year engineering and computer science classes. Since Northeastern has always tried to provide a unique learning environment, a LEGO® Mindstorms based course seems to be an excellent way of upholding this ideal. Courses involving LEGO® Mindstorms have also proved to be beneficial in several educational studies.

A study performed by Pomalaza-Raez and Groff [10] showed that an introductory engineering course taught using LEGO® Mindstorms increased the student retention rate significantly over a six year period. This course is an introductory course for the School of Engineering, Technology and Computer Science (ETCS) at Indiana University-Purdue University Fort Wayne. The first year the class was instituted the percentage of students that remained in ETCS after their first year was only 51.72 percent. This percentage is the total number of students that remained in ETCS after the introductory class divided by the total number of students in the introductory class. The class was taught in both the fall and the spring semester for the next five years. After the fifth year the percentage of students that stayed with ETCS had risen to 95.92 percent. This introductory class has greatly increased the retention rate of first year engineering students by creating an active hands-on class that excites students about engineering and technology [10].

Section 4: Recommendations

A course taught with a problem-based, active learning approach using LEGO® Mindstorms robots will not only increase retention rates but also improve student attitudes towards engineering. A prototype course that integrates both problem-based and cooperative learning would greatly increase student interaction and critical thinking. This course will use robotics as a way of conveying essential design principals to groups of students. The most significant change to the current Engineering Design course will be the addition of a LEGO® Lab where students will work together to create robots and solve problems. Some smaller changes have also been recommended to other aspects of the course, with as little change to the core material as possible. This section will explain all the changes to how the course is taught, the schedule and the budget. A full set of course documents that includes a syllabus, overview, sample projects and course material is included in Appendix [1].

4.1 Course Philosophy

The prototype Engineering Design course will have the same course goals and objectives as the original. In order to build upon the current course a few course goals need to be added. In particular, the students will receive more understanding of real world applications because the LEGO® Lab will be run in a professional environment. Making it professional will introduce the students to many problems they will face after graduation. For example, the first group that finishes a proposal could easily get some of their design ideas stolen. An activity like this one would teach students ethics and also that being the first to market is not always the best business decision. Similarly, the students will need to come up with a design and then submit a budget (a certain number of LEGO® components) from which they will learn resource management. By creating a professional environment the students will get experience in many aspects of engineering but also professional skills such as time management and responsibility.

Another important addition to the course goals is to increase the students' teamwork and communication skills. Many of the attached projects in Appendix [1] allow students to rotate into different roles for each new project. By changing into different roles of the team the students are constantly given a new set of objectives and responsibilities similar to what they may see in the professional world. This technique is also helpful to let students figure out what part of the engineering process they like the most. It gives students a chance to be designers, managers, testers, builders and programmers. This experience can help students choose the right major or field of study.

4.2 Course Schedule

This prototype course will require a different schedule then the current Engineering Design course. It is important to have more class time than only two classroom sessions and a computer lab. A LEGO® lab will be required in order to give students enough time to finish LEGO® design projects. The LEGO® lab is vital because students will need time to build and program the robots before they can be tested. This lab can be a separate one-credit class or just integrated into the course itself. The two classroom sessions will be unchanged so that the prototype course will still be able to easily cover the same curriculum. The computer lab is also a necessary component of the class and will be used to not only teach AutoCAD and Microsoft Excel but also give students some extra time to work on their robotics programming.

Some possible schedules are listed in Table [2]:

Table [2]: Possible Class Schedules

Monday	Tuesday	Wednesday	Thursday	Friday
A – Lecture		A – Lecture	A – Computer Lab	A – LEGO® Lab
B – Lecture	B – LEGO® Lab	B – Lecture	B – Computer Lab	
C – Lecture C – LEGO® Lab		C – Lecture	C – Computer Lab	
D – Lecture		D – Lecture D – LEGO® Lab	D – Computer Lab	

This table was put together with the knowledge of how Northeastern creates the semester schedules. The best possible schedule would be schedule A because it places the LEGO® Lab at the end of the week where it can tie together the LEGO® design project and the design topic of the week.

4.2.1 The Lecture

The formal lecture will be useful for students because it allows the professor to teach the essential design principals and the historical references in the curriculum. This is also an excellent time to go over homework and answer any formal questions about the topics covered. However, some small changes can be made to the formal lecture that will greatly enhance student knowledge retention. If the classroom activity is a formal lecture or a movie the professor can enhance the experience in several ways.

By taking periodic breaks during the lecture to allow students to clarify their notes with others the students will enhance their short and long term retention. For a sixty minute class there should be at least four breaks. These breaks need to only last one to two minutes to allow students a chance to gather their notes and collect themselves for another section of the lecture. This can also give the professor time to prepare a brief video segment or other visual aide.

Another technique that could enhance a formal lecture is to try and create a discussion. By opening up a discussion into a topic students can actively engage in the subject. For example, this technique would work very well with the topic of engineering failures. After giving a formal lecture on engineering failures take the next class to discuss maybe four or five examples and have students try to point out where the problem was and possible ways of avoiding or fixing it. By letting students actively engage in the formal lecture the results on assessments will definitely improve.

4.2.2 The Computer Lab

An essential component of the Engineering Design course is AutoCAD and Microsoft Excel. These topics can not be removed from the course but they can be changed slightly to accommodate an active learning approach. By giving students some problems in groups it will help increase student understanding. For in class lectures a similar break method is recommended to help students stay focused. In order to do this the AutoCAD or Microsoft Excel lesson should be taught by running a tutorial. This tutorial will have the professor explain and then show students how to perform a certain task. Then the students will have to follow the same steps and submit the finished product at the end of class. By doing this it will guarantee that the students will stay focused and also learn the required material.

Any extra time the students have during the computer lab should be used to program their robots. Since programming knowledge will vary from student to student a diverse set of languages will be given. For those students with limited programming skills the use of the basic RCX code will be assigned, for those that have programming knowledge the BrickOS platform will be used to allow students the chance to increase their C or C++ programming skill. The prototype course should attempt to integrate the AutoCAD course as much as possible into the assigned LEGO® Design problem. In the projects in Appendix [1] there is an AutoCAD section where the students are required to create a drawing that relates to the project.

4.2.3 The LEGO® Lab

The LEGO® Lab should take place towards the end of each week. This class will tie the problem and the topic of the week together. This will be where students will get extra time to finish up their robots and test them out. While the testing occurs, the professor will have time to consult with groups about their designs and proposals. These discussions should focus on what the team hopes to do better in the next assignment.

Since the students see the project from start to finish it is easy for them to identify what step they need to focus on in the future. Each week the groups will have to focus on a different aspect of engineering so the engineering process will need to be dynamic and the students will need to show their creativity. A set of possible LEGO® Design projects is given in Appendix [1] and many more activities can be found on the internet and in several other books [2,11,12]

4.3 Budget

This course will require a different budget from the current Engineering Design course. While the students will still need to purchase the *Engineering by Design* textbook that the current course uses the university will need to provide the other equipment. Assuming the average size of the class is about thirty students, the class will require ten Robotics Invention Systems 2.0, which have a price of $200 each. The software for the lab is free; therefore it will require no addition to the budget. There is also an option to purchase any number of other books on both LEGO® Mindstorms [11,12] and C++ programming. If the need arises, more information can always be found on the internet [2]. Therefore, in order to effectively create an active learning experience for students, the budget for the course will need to be increased by at least $2000. However, this is a small amount to add for the increase in student attitude, knowledge retention and professional skills.

Section 5: Conclusion

The creation of an active learning Engineering Design course will increase student retention rates, knowledge understanding, test scores and attitudes towards engineering. Several studies have shown the benefits and reasons for making changes to a conventional lecture based course. Even if only a few of the smaller recommendations were considered the class would benefit. These changes do not need to stop with Engineering Design. If the prototype course succeeds it will be an excellent chance for the College of Engineering to experiment with educational theory. Many other engineering courses could be integrated into an active learning approach using the same techniques recommended here.

The College of Engineering has always been the most ambitious department at Northeastern. By creating and testing some new educational theories the Northeastern College of Engineering will prove that they provide an educational experience like no other. The College of Engineering does not have to be the only department to benefit from this educational testing. Many of these techniques could be added into any lecture based course, and many of the active learning methods could work extremely well for practical courses. By making a few small changes in each class Northeastern University will uphold the motto of “Higher Learning. Richer Experience.” and may be that much closer to the final goal of reaching the top 100.

Appendix [1]: GEU 110 Robotics in Engineering Design

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Introduction

This appendix contains a collection of ideas that could possibly be used in a prototype Engineering Design course. These are only basic ideas given as examples to show how creative activities can relate to engineering topics. This should not be taken as a finalized course recommendation, but as a possible plan of action. There are literally hundreds of possible projects that could be created for any robotics based engineering course. The LEGO® Company and several website have course material readily available on the World Wide Web. Also, many textbooks have been created for LEGO® Mindstorms robotics.

In this appendix there is an updated Course Outline. This outline only has minimal changes because the goal was to try and keep as much original curriculum as possible. Also this appendix contains a syllabus which lists the current syllabus for the course with the added LEGO® Lab design projects. Finally the projects section lists an overview on how projects should be assigned and assessed. This project section lists several possible ideas for projects and how they relate to Engineering Design.

NORTHEASTERN UNIVERSITY

College of Engineering

Robotics in Engineering Design

GEU 110 COURSE OUTLINE

Course Number:	GEU 110	**Instructor:**	COE Staff
Quarter Offered:	Fall 2005	**Office:**	220 Snell
Total Credit Hours:	4 credits	**E-mail:**	
		Phone:	

Weekly Format: 2 Lectures, 1 Computer Lab, 1 LEGO Lab

Office Hours: By Appointment

COURSE GOALS:

- Introduce students to the engineering profession and creative engineering problem-solving through design projects, presentations, and activities.
- Familiarize engineering students with the various engineering disciplines, the focus of each of the disciplines, and their interrelationships.
- Provide historical perspective on engineering design processes, successes, challenges, and failures and their influence on contemporary society and modern engineering.
- Give students a chance to solve real world problems in a professional atmosphere
- Involve students in hands-on engineering educational activities through LEGO Mindstorms Robotics
- Inspire and instill an appreciation for the engineering profession, its ethics, and practices.

COURSE OBJECTIVES:

- Learn and apply all of the steps of the engineering design process in proposing and building working devices or models in design projects.
- Design and construct a working device or model that meets preset constraints and specifications.
- Review and evaluate engineering failures and successes for their relationships to engineering design problems, solutions, and processes.
- Conduct a needs assessment to design a product or engineer a solution by applying the engineering design process steps and documenting and reporting on each phase.
- Describe the scientific principles and technical background required for the proposed design project.
- Outline the patents related to the proposed design and evaluate their pertinence to the solution.

- Apply the engineering principles revealed in class exercises on teamwork, creativity, problem solving, and on evaluation, selection, and implementation of solution alternatives.
- Develop and apply drawing and sketching skills through AutoCAD to communicate design and engineering information graphically. Apply the principles of orthographic projection in design.
- Formulate engineering problems for numerical solutions; conduct relevant computations, analyze, organize, and present results using Microsoft Excel software.
- Create and deliver individual and team presentations on engineering design projects and topics.
- Generate a report for each design project that reflects work completed in each step of the design process and present technical drawings that apply to the relevant design.

REQUIRED MATERIALS & RESOURCES:

1. *Engineering by Design 2nd ed,* G. Voland, Pearson Prentice-Hall Publishing Company, NJ, (2004).
2. *Discovering AutoCAD 2004,* Mark Dix and Paul Riley, Prentice-Hall Publishing Company, NJ (2004).
3. Two 3.5" diskettes; optional: Zip® disk. Come to lab prepared to back up all of your AutoCAD work.
4. A **coe** (College of Engineering) e-mail account that you check and use regularly for course purposes. An account can be obtained through the Account Request link at: http://www.coe.neu.edu/computer

RECOMMENDED MATERIALS & SOFTWARE USED FOR SKILL-BASED LEARNING:

1. Reading*: Introduction to Excel 2002,* D. Kuncicky, Prentice-Hall Publishing Company, NJ (2003).
2. Reading*: Quick Start Guide to computer control and robotics using LEGO Mindstorms for schools*
3. Software*: Microsoft® Excel or Microsoft Office '97, 2000 or XP with Word, PowerPoint, and Excel.*
4. Software*: AutoCAD® 2004 (or AutoCAD 2002).*
5. Software: *BrickOS (*http://brickos.sourceforge.net)

CAD LABORATORY:

208 Snell Engineering is the ECALC Lab: Each Thursday, the Lab module will be held in this facility.

EVALUATION:

Final course grades will be computed using the following percentages:

10%	Minor Design Project
10%	LEGO Lab Assignments
10%	Homework and Attendance
20%	In-class Design Exams and/or Quizzes
20%	AutoCAD: Homework - 10%, Quizzes - 10%
30%	Major Design Project: Term Progress - 15%, Technical Report - 10%, Presentation - 5%

The Major Design Project will include a variety of interim assignments so that the instructor can provide feedback throughout the design process. The final technical report should include all relevant material contained in the earlier assignments and previously submitted work (possibly edited). Students are responsible for ALL topics covered in class and ALL assignment material. Design quizzes and examinations are CLOSED BOOKS and CLOSED NOTES. Late assignments are not acceptable.

LEGO LABORATORY:

Room yet to be confirmed.

READING ASSIGNMENTS:

Students should read the sections in the text indicated on the course outline prior to the lecture in which the material will be discussed. It is not expected that you will fully understand the material at that time. Reading first and identifying what you are unclear on, or have deeper interest in, will make it easier in class and facilitate meaningful questions and discussions.

WRITTEN ASSIGNMENTS:

All homework assignments must be submitted on time and word processed unless otherwise indicated. You may clarify minor aspects of your work with other students. You may not copy the work of another student nor fully collaborate to complete an entire problem. Therefore, unless it is work on a designated team project, all work submitted must be your own.

When doing drawings or sketches, use pencil, label components and drawings clearly and always use a straightedge.

SPECIAL ACCOMMODATIONS:

If you have specific physical, psychiatric, or learning disabilities that you believe may require accommodations for this course, please meet with me after class or during my conference hours to discuss appropriate adaptations or modifications which might be helpful for you. The Disability Resource Center (DRC), which is located on campus in 20 Dodge Hall (extension 2675) can provide you with information and other assistance to help manage any challenges that may affect your performance in your coursework. The University requires that you provide documentation of your disability to the DRC.

ETHICAL BEHAVIOR:

No collaboration is allowed on individual assignments under penalty of failure. Plagiarism, cheating, and any form of unauthorized collaboration will not be tolerated and will be handled in accordance with University policies described in the Student Handbook. All engineering majors are required to be familiar with the Honor Code of our College of Engineering that is included in the GEU 100 course material, and with professional engineering codes of ethics (see, for example, the NSPE Code of Ethics presented in the *Engineering By Design* textbook on pages 511-514).

Although students are encouraged to discuss some homework assignments and work together to develop a deeper understanding of the topics presented in this course, submission of others' work, efforts, or ideas as your own is not permitted. Each student is expected to prepare and submit his/her own programs, reports, drawings, and other materials unless otherwise designated as collaborative work.

Copying and sharing of student work such as computer files, documents, spreadsheets, or drawings is not allowed. If multiple students' work is suspiciously similar, a penalty may be assessed to both students. If a situation arises in which you are uncertain whether cooperation with another student would constitute cheating or some other violation of the honor code, please ask the instructor for guidance and clarification of these rules. Suspected violators will be referred to the Student Court for review, where penalties may include but are not restricted to: zero credit for the work, student placed on probation, submission of judicial findings in the students' permanent record, jeopardizing the students' status in the Engineering Program.

Expectations From the College of Engineering:

(1) We expect that you will successfully learn the course material and that your work will earn a fair grade. This will require a reasonable amount of work on your part. If you satisfy the remaining expectations, you will be well on your way to success in Engineering Design.

(2) We expect that you will complete the assigned readings before coming to class.

(3) We expect that you will attend every class, take comprehensive notes and participate (you are not simply a recorder). We expect that you will study your notes and the required texts and apply the relevant information as appropriate.

(4) If you miss a class, we expect that you will get the notes from a classmate and review them before the next class and discuss your absence with me.

(5) We expect that you will do your homework and submit it in accordance with given specifications on the due date.

(6) We expect that you will organize a study group for this course. We know of no better way to overcome hurdles when doing homework or to prepare for an exam.

(7) We expect you to be an active learner and take responsibility for learning the material – it is not just surviving homework assignments and exams. Seek help from Professor Jaeger or from members of your team, study group, tutors, or Student Services (220 SN).

(8) We expect that you will treat other members of the class with respect and not represent the work of others as your own.

(9) We expect your project team to work together on all aspects of your design project. If there are any conflicts or problems, we expect you will resolve them or bring them to me early in the semester to be resolved. We expect your team to work as professionals to accomplish your common goals for your projects.

(10) We finally expect and hope that we will have a good time and learn a lot of applicable material, competencies, and concepts.

COURSE SCHEDULE GEU 110 Fall 2004 (*revised*) Proposed Timeline

WEEK	ASSIGNED READING: TEXT – Voland, 2nd Edition COURSE TOPICS & DESIGN WORK	LEGO ® Lab Design Project	AutoCAD READING & LAB TOPICS, TEXT: Dix & Riley (2004)
1 6 September	Chapter 1; Course Overview ➔ Engineering Design #0D: Like/Dislike Design Example: Presentation & Write-up #1D: Engineering Design Analyses: Text problem 1.2, page 27	**Introduction to Robotics**	**D** - Design Assignments } *Abbreviation* **L** - Lab Assignments } *Notations* **No** Lab Meeting this week
2 13 September	Chapter 2; Design Process ➔ Needs Assessment #2D: Minor Design Project Description Handout: Proposal and Presentation Dates given	**Maze Runner**	**AutoCAD** & Assignment #1L Chapter 1: Lines; Getting Started Chapter 2: Circles; Other Objects
3 20 September	Chapter 2; Establishing Need and Reasons for Engineering #3D: Wright Brothers Worksheet and Film #4D: Chapter 2 Cases Selected	**Maze Runner**	**AutoCAD** & Assignment #2L Chapter 3: Layers, Colors, Fillet; Multiviews, Zooming, & Previewing #1L due
4 27 September	Chapter 3; Needs Assessment ➔ Problem Search #5D: Major Design Project Interest Areas & Team Member Preferences	**Perfect Putting Green**	**AutoCAD** & Assignment #3L Chapter 4: Template Drawings; Array Chapter 5: Arcs & Polar Arrays; Rotate #2L due
5 4 October	Chapter 1 (Review); Engineering Design Process: Work in Engineering Project Zone on Minor Project	**Perfect Putting Green**	**EXCEL** & Assignment #4L (a) MATHEMATICAL SOLUTIONS (b) SPREADSHEET CAPABILITIES #3L (AutoCAD Quiz Practice) due
6 11 October	Chapter 3; Problem Search & Formulation (*continued*) #6D: Major Design Groups Assigned - First Group Meeting	**Marble Madness**	**AutoCAD** Quiz 1 in Lab Chapters 1-5 Open Book, Open Notes
7 18 October	Chapter 4; Structuring the Search for a Solution: Goals #7D: Major Design Project Proposal Guidelines Chapter 6, Section 6.8 only for EXCEL Lab, pp. 246-256	**Marble Madness**	**EXCEL** (a) GRAPHING DATA AND ESTABLISHING TRENDS & Asmt #5L (b) SURVEY
8 25 October	Chapter 4; Solution Search ➔ Goal Definition Review Activities for Quiz and Preparation for Major Project Chapter 6, Section 6.8 *only*: Functional Graphs and Charts	**Urgent Package**	**AutoCAD** & Assignment #6L Chapter 6: Object Snap, Break, Extend Chapter 7: Text & Dimensions; Editing #5L Excel due

COURSE SCHEDULE (*continued*) **GEU 110 Fall 2004 (*revised*)** **Proposed Timeline**

WEEK	ASSIGNED READING: TEXT – Voland, 2nd Ed. COURSE TOPICS & DESIGN WORK	LEGO ® Lab Design Project	AutoCAD READING & TOPICS TEXT: Dix & Riley (2004)
9 1 November	Chapter 5; Engineering Graphics & Technical Knowledge; Chapter 6, Section 6.7 *only*: Sketching #9D: Engineering Graphics & Sketching	**Urgent Package**	**AutoCAD** & Assignment #7L Chapter 8: Dimensions & Dimensioning #6L due
10 8 November	Chapter 5; Technical & Background Knowledge ➔ Chapters 6 & 7; Abstraction, Modeling, & Synthesis #10D Goals & Background Information for Major Project	**Treasure Hunt**	***OFF: Thursday 11 November - Veteran's Day*** 🡐🡐 ***LAB meets on Wed 10 November in 208 SN***
11 15 November	Chapters 6 & 7; Abstraction, Modeling & Synthesis Design Quiz 2 Topics listed #11D: Abstraction & Synthesis & Analysis of Alternatives	**Treasure Hunt**	**EXCEL**: (a) SOLVING TECHNICAL PROBLEMS & PRESENTING SOLUTIONS (b) GENERATING A DECISION MATRIX in Lab #8L due Spline Homework
12 22 November	Chapter 8; Engineering Ethics & Product Liability	**Treasure Hunt**	***OFF: Thursday & Friday 25 & 26 November: Thanksgiving Break***
13 29 November	Chapter 10; Analytical Decision-Making, Quiz Prep Major Design Project Presentation Guidelines given #12D: Peer Rating of Team Members Distributed	**Treasure Hunt**	**AutoCAD** Quiz 2 in Lab Chapters 1-9: Open Book Open Notes Solid Modeling Packet Distributed
14 6 December	Chapter 11; Design Analysis ➔ Implementation Project Presentations ≤ 10 minutes		Thursday 9 December: Reading Day ☺
15 13 December	**FINAL EXAMS:** No formal final exam for this course; Major Project Papers due Tuesday 14 December by 12:00 noon at Prof. Jaeger's office 363 SN		

LEGO® Lab

Introduction

The LEGO Lab should be run like any other laboratory at Northeastern University. Teaching assistants (TAs) would greatly help this lab. In order to find quality teaching assistants a similar technique to the one used for peer mentor for Intro to Engineering should be used. The TAs need very little training and after the first year the class is run an abundant amount of trained students will be available. Students will need to get into groups of three or more for most lab activities. It is recommended that students try to change the way they contribute to the group in each new project.

Schedule

All labs should hold to the same schedule. The first part of the lab should be dedicated to the description of the problem and the brain storming of ideas. When teams feel they have created a solution they should present it to the professor or TA. If the professor or TA feels that the solution could work the idea gets an approval. Once the idea has been approved the group must create a budget for their solution. This budget should contain the pieces they intend to use. Students will be encouraged to be generous on the budget for the first few activities until they become totally comfortable with the LEGO® Mindstorms robotics. Once a budget has been submitted the students will get a chance to start building. The group can work at building and programming the robot at the same time. This will take up the main part of the lab so that is why many of the labs last for more than one session. Before the students are graded they will have a chance to test their robot a number of times (limited in the later projects) to make sure it creates a solution. When this is all finished the students prove they have a solution to the professor or TA. For each project the students must individually submit a report that explains what part they played in the group for the given activity. This paper should include what contributed to the group, what they learned from the exercise, and what they hope to improve on the next project.

Grading Criteria

Proposal	**10%**
Budget	**10%**
Design	**25%**
Programming	**25%**
Report	**30%**

Proposal

The proposal should be given full credit if it is on time and could possibly work. Students should be given a chance to adapt their proposed solutions during the testing phase.

Budget

The budget should receive full credit if the students are able to stay under it. During the later projects the groups with the smallest budgets should receive bonus points to show how economics can play a big factor in design.

Design

A group will receive full credit for their design if it provides a solution to the problem. If the group fails to solve the problem and it is due to the design or building of the robots then points should be deducted.

Programming

If the group is able to solve the given problem then they should receive full credit for programming. However, if the group fails to find a solution and it is a problem with the programming not the actual design then the programming score should lose points.

Report

The report is the most important part of the entire project. It should be graded on if the student clearly explains what they contributed to the group, what they learned from the lab, and what they hope to do better during the next project. If the group failed to find a solution to the problem that should be mentioned in the report. Also, the student should try to explain what went wrong and possible ways of avoiding or fixing the error.

Project List

Introduction to Robotics
Maze Runner
Perfect Putting Green
Marble Madness
Urgent Package
Treasure Hunt

Title:	**Introduction to Robotics**
Project Description:	The goal of this project is to introduce students to LEGO® Mindstorms robots. With every LEGO® kit a set of basic instructions is included. This is also posted on the internet. Student groups will get a chance to do several of the more challenging labs that explain how the input sensors, programming and output components all work together. For more information on this introductory session look here: http://www.lego.com/education/mindstorms/images/eng/downloads/led_quick_start_guide_eng.pdf
Skills Used:	Students will create their groups and also need to be able to follow directions. This lab is fairly simple but it also leaves some room for students to explore their own creativity.
AutoCAD Assignment:	None

Title:	**Maze Runner**
Project Description:	In this project the students will need to create a robot that can navigate a simple maze. This maze will be a rectangle and have only one path to completion. The goal is to have students design a robot that reacts to bumping into a wall with a change of direction. If the students are very proficient they will program their robots to navigate the maze without ever touching the wall. The students should be given an unlimited amount of test runs as long as time permits. During the proposal the students should explain how they plan on programming their robot. The budget should be left fairly vague so students can become more familiar with the LEGO® robots.
Skills Used:	Students will have a chance to explore their own creativity. Also the students will need to understand resource management when creating a budget. During the first few weeks of the course the students are introduced to the engineering design process, which they will need to apply to this project. Students will also get experience learning from testing their robot. This will be important because it is the first time the students are left on their own to test and fine tune their own robots.
AutoCAD Assignment:	The students will be learning how to create lines and simple drawings. For this project the students will need to map out the maze with all the correct dimensions.

Title:	**Perfect Putting Green**
Project Description:	The idea of the perfect putting green is to develop a new indoor putting practice system for your boss. This means that the robot needs to send the ball from a cup back to the putter at the end of the putting green. This project is left open ended on purpose so that students can explore several different options. The professor will then be able to actually test out the robots when they are finished.
Skills Used:	Since this problem is left so open ended students will be allowed to explore many different solutions. This will allow students to not only work on their creativity but also critical thinking when trying to decided what proposal has the greatest chance for success.
AutoCAD Assignment:	The students will be learning about circles and other shapes. Creating a drawing of the cup would be an excellent exercise for the students to prove their knowledge.

Title:	**Marble Madness**
Project Description:	This project involves a cleanup operation. A runway at Logan airport is covered in snow. The snow must be removed before any planes can land. The runway is a 6ft. by 3ft. rectangle that will be covered in marbles. The marbles will serve as the snow. The goal of the project is to remove all of the snow. Extra points should be given to any group that can not only remove all of the snow but also find a way to contain it rather than simply shove it out of the rectangle.
Skills Used:	By adding in a primary and secondary challenge the students will need to decide if they want to go for the extra points or just try to complete the assignment. Also, this project is left open for students to design any sort of robot to complete it. By now the student should be able to submit a good budget and stick to it. Also, all members of the group should be getting a good idea of what part of the engineering process they enjoy the most.
AutoCAD Assignment:	A good assignment could be to have the students create a drawing that displays the different color and size marbles. This will be an excellent way to combine all of the lessons until this point.

Title:	**Urgent Package**
Project Description:	This project will be an interesting change of pace for all the students. To complete this project two groups of students need to work together in order to bring a set of packages to a certain place. The idea is that one group designs a package distribution robot while the other creates a currier robot. Making the robots work in parallel will give students a chance to explore different networking ideas and communication skills.
Skills Used:	This project provides a unique chance for students to work together in larger groups. Also, this project requires so more complex programming in order for the two robots to work together. The students should be very comfortable with their budgets and also be proficient in coming up with ideas and creating proposals.
AutoCAD Assignment:	Students can create a drawing of the distribution system. By using different colors and different types of the lines the students can map out how the system should work.

Title:	**Treasure Hunt**
Project Description:	This project will be the final component of the LEGO® Lab. This will try to tie together all the different topics covered in this course and also add in a lot of fun. The basic idea for this activity is that students are given a set of directions to find three treasures. They must then create a robot that can retrieve all three. The students will not be given a chance to see the actual treasure hunt setup. Part of the assignment will be for the students to try and create the environment from the instructions given in the description. They will have to test their robot on this environment and then on the final day put the robot to the test in the actual treasure hunt.
Skills Used:	Here students will have the challenge of not being able to visualize the environment. Also, students should network with the other groups to try and get the best possible idea of the treasure hunt. This assignment will take a long time to program because the tasks are rather complicated and advanced.
AutoCAD Assignment:	The students will design the treasure hunt environment. Each group is given a set of instructions on how to find the treasure and it will be up to the groups to figure out what the entire environment actually looks like.

Works Cited

1. Prince, Michael, "Does Active Learning Work? A Review of the Research," Journal of Engineering Education, pp. 233-231, Jul 2004.
2. http://www.lego.com
3. http://brickos.sourceforge.net
4. Ruhl, K., C. Hughes, and P. Schloss, "Using the Pause Procedure to Enhance Lecture Recall," Teacher Education and Special Education, Vol. 10, Winter 1987, pp. 14-18
5. Springer, L., M. Stanne, and S. Donovan, "Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta Analysis," Review of Educational Research, Vol. 69, No. 1, 1999, pp. 21-52
6. Norman , G., and H. Schmidt, "Effectiveness of Problem-Based Learning Curricula: Theory, Practice and Paper Darts," Medical Education, Vol. 34, 2000, pp. 721-728
7. Klassner, Frank, "a Case Study of LEGO Mindstorms'™ Suitability for Artificial Intelligence and Robotics Courses at the College Level," IEEE SIGCSE, Feb. 27-Mar. 3 2002.
8. Williams, Andrew B., "The Qualitative Impact of Using LEGO® MINDSTORMS Robots to Teach Computer Engineering," IEEE Transactions on Education, vol. 46, no. 1, pp. 206, Feb. 2003.
9. Fagin, Barry and Merkle, Laurence, "Measuring the Effectiveness of Robots in Teaching Computer Science," IEEE SIGCSE, Feb. 19-23 2003.
10. Pomalaza-Raez, Carlos, and Groff, Brenda H., "Retention 101: Where Robots Go… Students Follow," Journal of Engineering Education, pp. 85-90, Jan 2003.
11. Ferrari, M., Ferrari, G., and Hempel, R., Building Robots With Lego Mindstorms: The Ultimate Tool for Mindstorms Maniacs, Rockland, MA: Syngress Publishing, 2002
12. Erwin, B., Creative Projects with LEGO Mindstorms, New York: Addison-Wesley Professional, 2001

Annotated Bibliography

1. Fagin, Barry and Merkle, Laurence, "Measuring the Effectiveness of Robots in Teaching Computer Science," IEEE SIGCSE, Feb. 19-23 2003.
   Fagin and Merkle report the results of a year-long experiment using robots to teach basic computer science. The results are taken from a pool of over 800 students with identical tests using robotics and non-robotics based laboratory sessions. "The robotics laboratory was commonly described as 'interesting', 'fun', 'challenging' and 'relevant.'" This study will be useful in giving first hand statistic on how robots are effective in learning the topics but also in boosting interest and retention. Barry Fagin is a professor at the US Air Force Academy and Laurence Merkle is a professor at Rose-Hulman Institute of Technology. Both of these professors teach entry-level computer science and computer engineering.

2. Goldthwaite, Don, Personal Interview, Oct. 26, 2004
   Professor Goldthwaite explained that if he could change one thing about the GEU 110 Engineering Design course it would be to teach it in a more problem-oriented fashion. He believes that active learning would fit incredibly well into such a class. Also it was apparent that Professor Goldthwaite sees true value in teaching engineering principles through robotics. I plan to use the information he has provided me to explain the GEU 110 course as it is currently being taught and I also hope to sit in on a few classes to gather more information.

3. Klassner, Frank, "a Case Study of LEGO Mindstorms'™ Suitability for Artificial Intelligence and Robotics Courses at the College Level," IEEE SIGCSE, Feb. 27-Mar. 3 2002.
   Klassner examines LEGO Mindstorms'™ suitability as a hardware platform for integrating robotics into an artificial intelligence course at the college level. "The paper's investigation also examines several popularly-perceived limitations of the Mindstorms package for college-level robotics projects and shows that most of these "limitations" are not serious impediments to the Mindstorms' use…" This paper includes many examples and in an in depth case study of an actual class. This information is incredibly valuable for the recommendation and the use of LEGOs as active learning tools. Frank Klassner is a Computer Science professor at Villanova University.

4. Pomalaza-Raez, Carlos, and Groff, Brenda H., "Retention 101: Where Robots Go… Students Follow," Journal of Engineering Education, pp. 85-90, Jan 2003.
   Pomalaza-Raez shows that an engineering class, which is group and project oriented, using LEGO MINSTORMS, has a higher retention rate than a conventional class. "Robotic projects are multidisciplinary in the sense that they involve a wide range of disciplines, including computer science, physics, mathematics, biology, psychology, engineering and art." (pp. 86) I plan to use the information provided in this paper to compare interactive learning courses and conventional courses in term of retention rates. The author is a Professor at

Purdue University Fort Wayne and currently teaches an interactive engineering class using LEGO MINDSTORMS.

5. Prince, Michael, “Does Active Learning Work? A Review of the Research,” Journal of Engineering Education, pp. 233-231, Jul 2004.
Prince reviews all of the research surrounding Active Learning and argues that active learning is more beneficial than conventional learning. “Although the results vary in strength, this study has found support for all forms of active learning examined.” (pp. 229) The information provided in this paper will support my argument for active learning as compared to conventional learning. I will also use this paper to help define active learning and give good examples. Dr. Michael Prince is a Chemical Engineering professor at Bucknell University. Prince has written several papers on engineering education and also gives faculty development workshops on active learning.

6. Williams, Andrew B., “The Qualitative Impact of Using LEGO® MINDSTORMS Robots to Teach Computer Engineering,” IEEE Transactions on Education, vol. 46, no. 1, pp. 206, Feb. 2003.
Williams describes how LEGO MINDSTORMS robots were used as a hands-on educational tool to teach first year computer engineering. “Students responded very favorably to using LEGO MINDSTORMS robots to learn C programming and introductory embedded systems design hands-on.” (pp.206) The examples and information in this paper will be useful in showing the many different skills that can be taught using LEGO MINDSTORMS. Andrew Williams is a professor of Electrical and Computer Engineering at the University of Iowa.

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