Empowering Students to Become Highly Skilled Professionals for the 21st Century Industries

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Abstract

The paper presents the Senior Project (Capstone Course): a completely redefined scope and set of guidelines developed by the author that engages senior students in a 4-credits Research and Development course covering all aspects of project development and implementation, entrepreneurship, innovation, creativity, teamwork, and communication. The paper discusses the development of the course in the past two years, many of the factors leading to its accomplishments as well as obstacles encountered, and provides some metrics for the evaluation and grading of the students' projects. In particular, student projects that resulted in two pending patents and two refereed journal publications will be presented. The philosophy behind the course is to provide training and real world, small-scale project experience for the students. This is where students work in teams and apply the culmination of their knowledge in the program and go through a complete project lifecycle that includes project management, starting from a conceptualization of an idea, to proposal development and presentation, to design, implementation, and testing, and finally a finished product supported by the system prototype, presentation, and a full length technical report. Some of the features of the course such as University of Houston and industry guest speaker series and final project evaluation by the department's Board of Industrial Advisors, leading professionals in the relevant industry, faculty, technical staff and peer will be explained. The paper concludes by outlining a set of short term and long term goals for the direction of the course.

Introduction

The senior project courses across the engineering and engineering technology programs considered an important component of these programs. There exists a range of capstone course implementations but often students do not disseminate the experience and the results of their projects. Most papers published in journals, conference proceedings and presentations at the conferences appear to be the effort of the faculty leading capstone courses. The good news is that capstone courses continue to be scrutinized, reviewed and improved. In the past, most publications centered around general report on capstone course development, implementation and improvement [1, 2] and adding industry collaboration component to the capstone courses [3, 4]. After ABET 2K [5] release, established capstone courses added systematic assessment component [6, 7]. Recently, an interest to introduce entrepreneurship and commercialization into capstone courses were reported and they are on the rise [8, 9, 10, 11, 12, 13, 14, 15, 16].

The senior project course at the Computer Engineering Technology (CETE) program, University of Houston is a very young in its present format. As part of streamlining the CETE program in Engineering Technology (ET), it was decided to change the scope and redefine the course such that it was possible to measure the student mastery in the CETE program.

In the past several years, the course was taught under the *Microcomputer Interfacing*. The course consisted of three hours lecture and one hour lab. In its old format, the course covered topics such as Op-Amps, ADC/DAC, interfacing, signal conditioning, microprocessor I/O, bus structure, and some machine language. The course was more hardware intensive with very limited software component present and did not have any laboratory assistants. During the revision phase, the author identified that most of these topics were covered in earlier CETE curriculum. The lab component consisted of several small experiments during the first half of the semester and the second half of the semester was devoted to a term project (certainly not enough time for a meaningful team project experience). Students grouped in teams of two and proposed their idea to the lab instructor and the course instructor for approval. The students had to purchase their own parts and most often work outside of the lab, due to a limited lab space availability, to construct their projects. Most often, the course and lab instructors were different with very little interactions between them. Part-time faculty often taught the laboratory component. The author attended several of the earlier lectures and observed student projects while noting the deficiencies and changes that have to be implemented to make the success in the course a true measure of student mastery of the major.

The deficiencies observed in the course was traced back to the fundamental courses and gave rise to the birth of the CLABS (read as C- LABS) Project [17, 18, 19] in summer 2004. The CLABS Project was made possible with a change in administration of the college and department, hiring a new generation of energetic faculty and strong desire to change at all levels. The rationale behind the CLABS Project is reported in several publications [20, 21, 22, 23].

Effective fall 2004, the course was taught under *Senior Project* title in a new and modern laboratory space with a new scope and direction. In the following sections, details of the course, various assessments used in the course, accomplishments in the past two years, short term and long term goals will be explained and concludes with a conclusion.

New Format for the Senior Project

In its new format, the senior project class can accommodate maximum of 48 students and when possible, students work in teams of four students. Students are free to choose their team members. In few occasions, there were teams of three students because of enrollment. The prerequisite of the course is the Embedded Systems course. Two surveys are conducted during the first session. The first survey is a self-assessment of the student knowledge and information about their work schedule (most students work part time and few work full time). Similar survey is conducted at the end of the semester and the results are then compared. The purpose of this survey is to assess student’s knowledge and workload and provide guidance if overload schedule is identified. Figures 1 to 4 show samples of the questions and the results. As is often the case, most students overestimate their knowledge in the areas questioned and often have overloaded schedule. The end of the semester survey is more accurate compared to the beginning of the semester survey. Such results were consistent in the past few semesters. The second survey is the desired time blocks that the teams will require to use the lab outside the normal class schedule. The purpose of this survey is to schedule laboratory hours of operation. The course has three graduate assistants and they are selected from a pool of 8-12 candidates. Assistants go through an exhaustive interview process before they are hired. Each semester, all laboratory assistants in the ET department go through a two-day training prior to the start of the classes. The specific policies and requirements for the senior project course is provided by the faculty in charge. Each assistant normally spends between three to four semesters in the senior project class. Each assistant works 20 hours a week for the course.

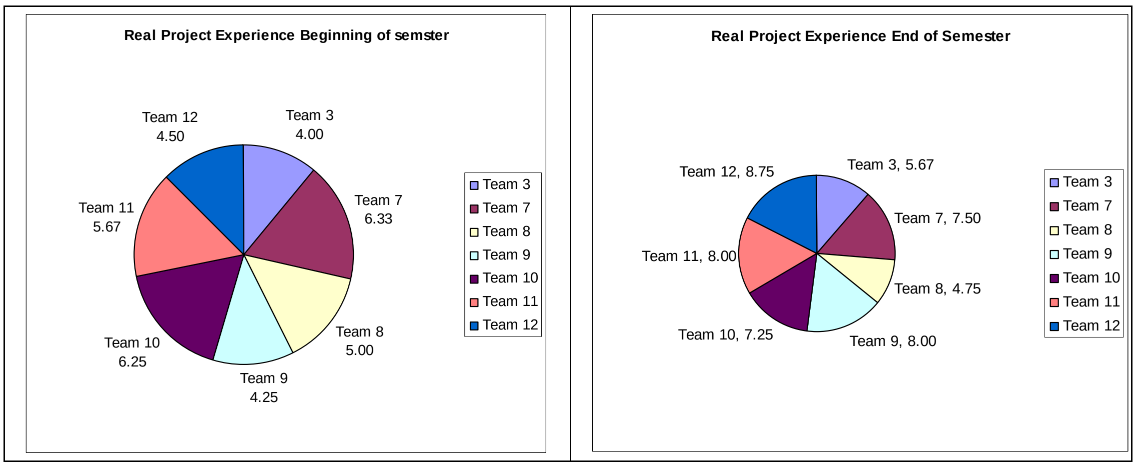

Figure 1: Real project experience.

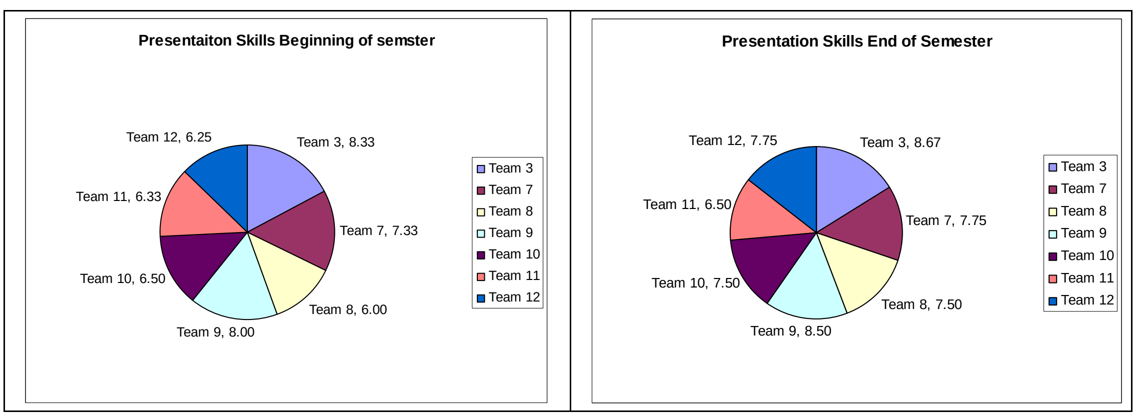

Figure 2: Presentation skills.

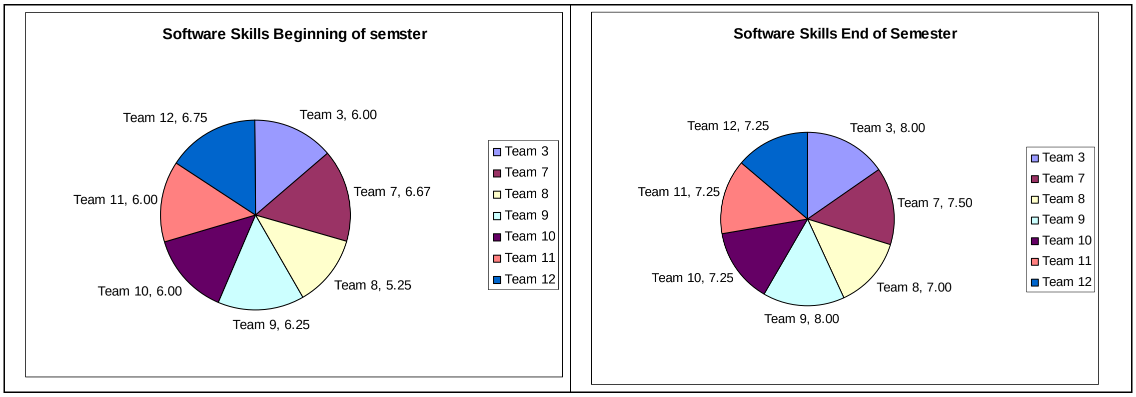

Figure 3: Software skills.

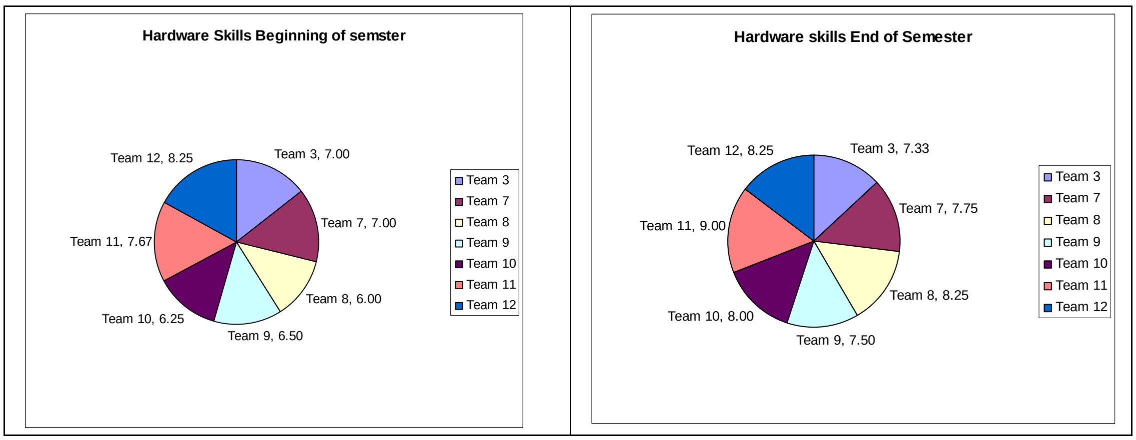

Figure 4: Hardware skills.

The laboratory hours span seven days a week with time blocks assigned according to the student requests and assistants' class schedule. Each team has a budget of $350 for their project. The faculty has the freedom to increase the budget once a promising project is identified and the team makes significant progress. The course is somewhat unstructured and teams must identify their own projects. Each team identifies at least three potential projects and discusses them with the faculty members and the assistants.

In the following section, components of the senior project course are briefly explained.

Senior Project Course Components

Books- Two books are assigned in the course. One on engineering design and the other covers creativity. Reading assignments are given routinely.

Lectures- Nine lessons are presented in the class. The lectures are synchronized with the two books and are supplemented with additional information. The lectures are presented in the form of discussions rather than the traditional lectures. The first lesson is an overview of the entire course. Students have access to the lecture notes through the course web portal, discussed later.

Homework- Each semester, four to five homework assigned. The homework has five to six questions and students work on the homework individually.

Exams- Closed book and notes midterm exam and final exam is given. Most questions are from the two books, lessons, guest speaker presentations and workshops.

Workshops- Three workshops are given at the beginning of the semester. The first workshop is a three-hour hands-on training to use the Microsoft Project. The Microsoft Project is used for Gantt chart to track teams' progress and is conducted by the Information Technology trainer at the University of Houston. In the second workshop, students are introduced to the UH policies regarding intellectual property and patent. The workshop is conducted by the office of Research and Intellectual Property Management. The third workshop is on research in technical and science libraries and is presented by the College of Technology Librarian.

Guest Speakers-The guest speaker series is designed to introduce students to the real world challenges. The speakers are engaged in the cutting age of their industry. They often bring in a new perspective to the senior project. A few of the speakers are members of the ET industrial advisory board and are familiar with the curriculum and provide valuable feedback for the improvement of the senior project course. Others are entrepreneurs and CEOs and enlighten the students by discussing the success of their companies.

ET Faculty Speakers- Volunteer faculty members who are interested in mentoring students present their research and expertise. A separate policy governs the ET faculty mentorship. There is *no* separate grading standard for this group of students.

Laboratory Assistants Presentations- All assistants assigned to the course are formally introduced to the students. Each assistant makes a short presentation and students will get to know them and understand the areas of their expertise.

Combined Documents- The combined documents provides senior project students with policies, detailed guidelines for the progress report, proposal report and final project, grading forms, evaluation forms, etc.

Web Portal- A secured access web portal is provided for the course where supporting course materials are stored. The web portal provides specific folders for the ancillary documents, project teams, laboratory assistants and the faculty directing the senior project course. The ancillary documents folder houses the Combined Documents, creativity and innovation papers, technical papers on sensors and stepper motors, microcontroller documentations, MicroC library functions; parts list available in the lab, lecture presentation slides and past student projects. The laboratory assistants' folder archives all progress reports, proposal reports, final reports, homework, mid term and final exams. This folder is also used for communications with the senior project faculty. The senior project faculty folder is used primarily for development purposes.

Progress Reports- Each team submits a weekly progress report. Specific guidelines and requirements are provided to the students. Two assistants and the instructor review all reports. The graded reports are returned and discussed with the students. A grading form is given in Appendix A.

Project Proposal- The project proposal consists of a presentation and report. Each team must clearly address the following items in their presentation and report:

- Benefits of the product or process to the end customer
- Project objectives tied to the project specifications
- Strategy for achieving project objectives
- Detail plan of action divided into a number of tasks to be performed by individual member of the project team to achieve the project objectives
- Time schedule depicting weekly progress and individual/team assignments
- Cost analysis
- Design verification procedures
- Procedures to quantify prototype performance

Two assistants and the faculty member grade the reports. See appendix B for the proposal evaluation form. The form has scores from other evaluations such as confidential peers in team and peers in class. Students receive their own evaluation form.

Final Project- The final project consists of a presentation, report and prototype demonstration. This is the most exciting event for the students and the department. UH Faculty, industry guests, staff and other students are present during the presentation and demonstration. The report consists of Executive Summary, Newsletter, Product Requirements, Design Specifications & Description, Construction Details, Cost Analysis, User Instructions, etc. Multiple evaluation forms are used during this event. The final evaluation form is given in Appendix C.

Grading- The student performance is determined by many metrics before assigning the final grade. The students receive the same grade for the course and the lab. The exams contribute 25% to the overall grade and the remaining 75% are distributed to other components of the course. The exams, confidential peer in team evaluation and faculty and assistants' evaluations differentiates the grade for each member of a team. Appendix D provides the grade breakdown.

Guest Speaker Survey- Immediately following each presentation and workshop, a survey is administered. The purpose of the survey is to understand what students like and dislike about the presentation or workshop. The summary of the surveys is relayed to the speaker.

In the next section, accomplishments in the past two years are discussed.

Accomplishments

In the past two years, the senior project students were able to secure two provisional patents and submit two papers for publication in the refereed journals [24, 25]. Three additional papers are in various stages of development. The two projects with provisional patents and two other projects are now briefly described. The first two projects were showcased at the Research and Scholarship Day in spring 2006 at the University of Houston. Other student projects for the past few semesters are posted at [26].

Robotic Bulldozer- Currently, bulldozers are the primary means by which a forest is made ready for new construction. Presently this task is given to a bulldozer operator who is responsible for pushing over trees and leveling the dirt to grade. Staying in control of the vehicle requires the total attention of the operator, so operator's skills are not fully realized. Further, the health risks associated with the operation of heavy machinery are of a significant concern to the operator. This project implemented the hardware and software implementation of a Robotic Bulldozer (Figure 5) which can be used to solve the above issues.

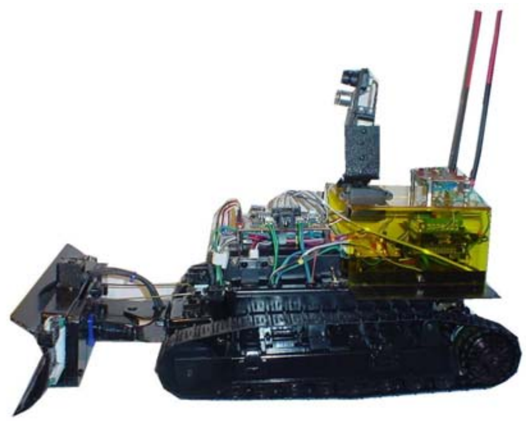

Figure 5: Robotics Bulldozer Prototype.

Once the system is activated, it will be given parameters at the start of a job that it will use to accomplish the tasks. The autonomous system may be remotely monitored and coordinated with other machines and employs by a remote operator to assure the system functions according to the designated tasks. The primary goal of this invention is to implement an autonomous system for the construction industry.

The Robotics Bulldozer is a fully autonomous system featuring multiple sensors and devices to gather the field data it requires to operate safely within the specified requirements. It is equipped with a Scanning Vision System, Collision Detection/Avoidance and Distance Measuring System, Terrain Scanning Elevation Mapping System, Tactile Blade Pressure Sensor System and Wireless Communications. All of these systems operating together will make the autonomous system the way of the future for the space, military, mining, agriculture, high tech toys and construction industries. A provisional patent protects the Robotics Bulldozer.

High Temperature Automobile Protection System (HiTAPS)- The High Temperature Automobile Protection System (HiTAPS), shown in Figure 6, is a safety alarm system for

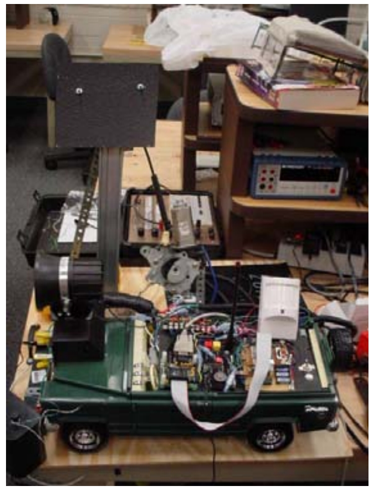

Figure 6: HiTAPS Prototype.

ensuring the safety of children and pets locked in a parked automobile during extreme temperatures. The HiTAPS circuit consists of a Mini-Max/51C-2 microcontroller board manufactured by BiPOM Electronics along with pressure and motion sensors for detecting the presence of children and pets inside the automobile. Whenever the microcontroller detects that the temperature inside the automobile reaches extreme values, in this case above 100^0F, and either a child or pet is detected to be present in the automobile, it activates the Radio Frequency (RF) transmitter unit that sends a signal to the owner of the automobile via their handheld receiver. If there is no response within two minutes, the windows are automatically lowered and an alarm is turned ON to alert others present in the area. A provisional patent protects the HiTAPS.

The Robotic Fertilizer Spreader (RFS)- The Robotic Fertilizer Spreader (RFS), shown in Figure 7, is capable of fertilizing a field that is relatively flat and obstacle free. The RFS provides a solution to manually fertilizing large fields by providing a semi-automatic fertilizer spreader. The RFS was designed and constructed using fertilizer tank, chassis, a driving motor, a steering motor, an odometer, a microcontroller and their interfacing circuits.

Figure 7: The RFS Prototype.

Along with the keypad, the RFS features an LCD screen that displays very user-friendly instructions. The RFS is equipped with a powerful 36-volt motor that can easily handle heavy loads and different terrains. The RFS also features superb stability with its wide four-wheel base and steel chassis. It is capable of carrying 200 pounds of fertilizer in the holding tank so it can hold plenty of fertilizer to complete a job. Spreading fertilizer over relatively flat obstacle free fields has never been this easy. Fertilizer is essential for healthy lawn growth and depending on the grass grown, 3 to 6 fertilizer applications should be made during the growing season. RFS is capable of doing the fertilizing in an easy fashion. All that is needed to be done is type in the length and width of the field with the provided keypad, turn the start knob and the RFS does the rest. The inputs to the microcontroller are the keypad and the Odometer. The output of the microcontroller is given to the Steering Motor control circuit, DC drive motor control circuit and the LCD that is used as a user interface.

Smart Trash Can (S.T.A.N)- The Smart Trash Can (S.T.A.N), shown in Figure 8, is a system that promotes a cleaner and safer environment. S.T.A.N. ensures safer and hygienic surroundings with the help of a number of sensors that include sensors which alert when the trash can is full or contains a high level of decomposing items and sensors to automatically open the lid when a patron is detected within a certain distance. The S.T.A.N core circuit consists of a Mini-Max/51C-2 microcontroller board interfaced with an IR distance sensor, methane detector, force sensor and other peripheral devices to communicate the status. The distance sensor was linked programmatically to the motor control relays to trigger opening and closing of the 'iris', a specially designed lid (Figure 9), when a user is detected at the

Figure 8: S.T.A.N. Prototype.

Figure 9: ‘IRIS’ as constructed.

trashcan. The opening routine sets the direction of the motor, and runs the motor until the “LidOpen” limit switch is activated. Once the “LidOpen” switch is activated, a timer is started to control how long the ‘iris’ mechanism will stay open before activating the closing routine.

Short Term Goals

The short term goals are summarized below.

- Capitalize on the accomplishments in the past two years
- Monitor the progress of the students as they go through the revised laboratories in the CETE program under the guidance of the CLABS Project initiative
- Encourage other faculty to take part in mentoring the students
- Improve the assessment instruments
- Encourage senior project students participation in department’s sponsored tournaments such as Botball [27], FLL (First LEGO© League) [28] and Houston Robotics [29].

- Pilot test senior project teams' participation in mentoring at least one group from the K-12 involved in various robotics activities. This goal raises students' social awareness and responsibilities. Additionally, it may lead to K12 students interest in STEM (Science, Technology, Engineering, and Mathematic) education
- Require senior project students to participate and act as judges in at least one final project presentations by freshman, sophomore or junior students and submit a report of their experience
- Pilot test the Duties of Senior Project Graduate Assistants document developed by the author
- Disseminate the information gathered in the past two years

Long Term Goals

The long-term goals for the senior project course require some challenges including time. Some efforts along these lines are currently underway and require additional resources.

The long-term goals are summarized below.

- Industry participation in mentoring and sponsoring student projects
- Facilitate industry internship for the students
- Joint projects with other departments within ET
- Joint projects with other schools at UH
- Participation in regional and national competitions
- Conference presentations by students
- More patentable projects
- More journal publications
- Increase student sense of community responsibilities

Conclusion

Internal support such as adequate laboratory space, tools and modern equipment conducive to innovation and creativity; graduate assistants support to monitor and assist the students on their projects, extended lab hours, incentive for students to do outstanding work and faculty with keen interest in continuously updating the teaching materials are part of a successful operation of a senior project course. Leveraging the service organizations of the institution to take part in the student training is highly desired. a faculty who has been in the industry and is current with the state of the art practices can contribute immensely to the nurturing of the students. External support includes industry participation in variety of forms such as sponsoring student projects, donations of parts, mentoring of the project teams, active participation during the final project presentations and evaluations are essential. Finally, a supportive administration and faculty is a must.

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Acknowledgements

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Biography

Dr. FARROKH ATTARZADEH is an associate professor in the Engineering Technology Department, College of Technology at the University of Houston. He teaches software design and programming, operating systems, digital logic, and is in charge of the senior project course in the Computer Engineering Technology Program. He directs the CLABS Project and the CORE (Coordination Of Robotics Education). He has been with the University of Houston since 1983. His areas of interests are in software development, embedded systems, project management, robotics and electromechanical folk art.

Appendix A

Department of Engineering Technology
Computer Engineering Technology
Senior Project
ELET 4308/ELET 4108
Spring 2006
Evaluation Form for Weekly Progress Report

Progress Report No.:

Team No.:

Team Members :____

Project Title : ____

Date Progress Report Submitted :______________________________________

Time Period Covered in the Report: ______________________To ________________

WPR Sections	Max Possible Points	Points Assigned	Comments
1. Project and Purpose	**2**		
2. Accomplishments from the previous week	**5**		
3. Planned activities for the current week	**5**		
4. Resources utilized 4.1 Labor usage 4.2 Financial resource usage 4.3 Project schedule Status	**5**		
5. Current or continuing problems	-	-	
6. Comments and suggestions	-	-	
7. Supporting Documents	**3**		
Total Points	**20**		

Please complete the top portion of this evaluation form in Word and turn it in with every weekly progress report.

Faculty Advisor (signature) _________________________ Date : / /2006
Dr. Farrokh Attarzadeh

Appendix B

ELET 4308/ELET 4108
Spring 2006
Proposal Evaluation Form

Team no.:
Project Proposal Title:
Team members
Instructor: Dr. Farrokh Attarzadeh

Criteria	Possible Points	Points Earned	Comments
▪ **Peer evaluation**-Peers in other teams	10		
▪ **Peer evaluation**-Peers in your team	10		
▪ **Faculty evaluation of the presentation** ▪	10		
▪ **Proposal Document:** ▪ Logical format ▪ Media ▪ Typographical errors ▪ Neatness ▪ Consistency ▪ Accuracy of information presented ▪ Completeness	12		
▪ **Introduction**	4		
▪ ***Project Objectives***	4		
▪ ***Project Description***	25		
▪ **Plan of Action**	5		
▪ **Verification**	3		
▪ **Cost Analysis**	5		
▪ **Project Schedule**	4		
▪ **References**	3		
▪ **Senior Project Questions**	5		
Points Possible	100		

Appendix C

Senior Project

ELET 4308/ELET 4108

Spring 2006

Final Project Evaluation Form

Team no.:
Project Title:
Team members:
Instructor: Dr. Farrokh Attarzadeh
Date:

Criteria	Possible Points	Points Earned R1( )	Points Earned R2( )	Points Earned R3( )	Comments
• **Peer evaluation**-Peers in other teams	20				
▪ **Peer evaluation**-Peers in your team	20				
▪ **Faculty & TAs evaluations of the presentation**	20				
▪ **Project Document:** ▪ Logical format ▪ Media ▪ Typographical errors ▪ Neatness ▪ Consistency ▪ Accuracy of information presented ▪ Completeness	20				
▪ **Executive Summary**	10				
▪ **Newsletter**	20				
▪ **Introduction**	5				
▪ **Background**	5				
▪ **Product Requirement**	10				
▪ **Design Alternatives**	10				
▪ **Design Specifications**	20				
▪ ***Design Description***	40				
▪ ***Construction Details***	25				
▪ **Costs**	10				

▪ **Conclusions**	10				
▪ **User Instructions**	20				
▪ **Project Schedule**	10				
▪ **References**	5				
▪ **Components of the Project Binder:**					
▪ A binder cover	3				
▪ A cover sheet for the documents inside the folder	3				
▪ Table of contents (for the documents inside the binder)	4				
▪ Senior Project Presentation Slides	10				
▪ Senior Project Report (refer to the guidelines specified in the document in this folder under the title "Senior Project Report)	--				
▪ Senior Project Proposal Presentation Slides	5				
▪ Senior Project Proposal Document	5				
▪ Progress Reports (organize them as 1, 2, 3, etc.)	5				
▪ Minutes of the meetings (organize them from the first to the last minutes of the meetings)	10				
▪ **Copy** of all the invoices from all the sources	5				
▪ **A CD containing**:					
(a) All of the above items with proper folder names,	10				
(b) All digital pictures with appropriate labels, chronicling the progress from the beginning to the end,	10				
(c) Any digital movie of your project, and	-				
(d) Any other useful information pertinent to your project	-				
Points Possible	350				

Appendix D

Senior Project
ELET 4308/ELET 4108
Spring 2006

Grade Breakdown

I. Midterm	**10%**			
II. Homework, proposal, progress reports, Project	**75%**			
Homework		**7%**		
Proposal		**18%**		
Presentation			8%	
Peer in class evaluation				1%
Peer in group evaluation				2%
TA evaluation				2%
Instructor evaluation				3%
Proposal Document			10%	
Progress Reports		**9 %**		
Final Project		**41%**		
Presentation			11%	
Peer in class evaluation				2%
Peer in group evaluation				4%
TA valuation				2%
Instructor & Guest evaluations				3%
Project Document			15%	
Prototype's Completion			15%	
III. Final	**15%**			
Total	**100%**			