Battlebots Laboratory – An Integrated Team-Based Design/Build Course

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Abstract

Today's educational institutions are undergoing major transitions as they deal with increasing enrollment and new technologies, while resources become increasingly limited. Engineering departments around the country are seeking methods to engage students in hands-on learning activities that focus on a team-based approach to design and engineering education. Curricula that emphasize design/build projects and offer students the opportunity to develop skills using tools, CAD, interactive design, and project management can become expensive and time consuming for the institution.

Herein an innovative pair of courses to supplement basic freshman engineering programs is described. This approach consists of two mutually supportive courses that expose teams of freshman engineering students to the basic design process through a team project, while allowing upperclassmen to take responsibility for team leadership and the project scheduling. The inspiration for this course comes from the popular television show "Battlebots", in which remote-controlled robots battle one another to "the death". In our course, the upper-class students serve as the team leaders and are responsible for all project management functions. The freshmen are responsible for the actual design and construction of their team battlebot. The result is a real-life, hands-on learning experience for each participating student.

The course structure provides a unique learning experience for all of the students involved. The freshmen gain valuable teamwork experience and learn to use tools, CAD software, and gain familiarity with gears, motors, electric circuits, and other electro-mechanical components. The upper-classmen gain experience as leaders and problem solvers, while planning and delivering a real project on time and within budget. This course manages to accomplish these objectives without a large expenditure of funds because the upperclassmen assume a role that would normally be seen as the responsibility of a paid teaching assistant. This "dual" course has been piloted during the Fall '02 semester at Virginia Tech and an overview of its implementation, and execution is presented.

I. Introduction

Battlebot laboratory courses have been used before as an educational forum. An article in the October 2002 ASEE PRISM magazine describes the benefits and opportunities afforded students by incorporating the excitement generated by the television show into an educational experience.[1] The article describes a senior-level design/build course that teaches various engineering skills in a fun, hands-on learning environment. Our concept was to offer this same type of opportunity to freshman engineering students so that they might develop these skills earlier in their academic careers. In addition to the educational value of this course, freshmen engineers also get another opportunity to meet with fellow freshmen, interact with upper-class engineering students, and enjoy a little friendly competition.

The Division of Engineering Fundamentals (EF) at Virginia Tech has developed this course to be two mutually supportive courses, one for upper-classmen and the other for freshmen. The first course is "Introductory Engineering Project Management – Robot", designated as EF 2974. This course is offered to a limited number of junior and senior engineering students who are selected based upon their motivation, people skills, and previous experience with other extra-curricular "club projects". The course provides an

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opportunity to learn and apply project management, leadership, oral and written presentation, teamwork, and modeling. Perhaps most beneficial for the upper-class students is the responsibility placed upon them for the planning, timely completion, and the ultimate success (or failure) of their teams' battlebot. The second course is designated as EF 2984 and entitled "Introductory Engineering Project – Robot". This course is available only to freshman engineering students and provides a hands-on introduction to the process of design, teaming skills, the use of hand and pneumatic tools, and written and oral presentation skills. These two courses are one credit hour each and meet once a week during a shared two-hour laboratory period where all construction must occur. These parallel courses culminate in the creation of a battlebot by each team. At the end of the semester, the battlebots must compete in a skills test and ultimately do battle with one another.

Combining upper-class and freshmen students into teams has advantages for both groups. The freshmen students learn and sharpen skills that will serve them during their education at Virginia Tech and beyond. The upper class students learn to lead people and manage materials, which will be useful as they embark on their careers as engineers. The institutional benefit of this arrangement is a cost savings because the presence of salaried teaching-assistants in the laboratory is unnecessary. The upper class students assume all team leadership responsibilities during laboratory time. In the long term, we hope to develop industry supported teams as the course expands in order to minimize material expenditures incurred by the college.

II. EF 2974, "Introductory Engineering Project Management – Robot"

Engineering students at Virginia Tech have the opportunity to enroll in project management courses that teach how to make milestone charts and use critical path management (CPM), but have little opportunity to practice these skills. This course is part of an on-going effort within the EF division to engage students in hands-on learning opportunities while increasing student interaction and mentoring. The robot project exposes upper class students to the complete project management experience as they manage all functions associated with a real project. Each management team consists of two co-captains that are given a mission statement, provided adequate resources, and a team of eight freshman-engineering students. The co-captains are then required to manage their materials and lead their team through the design process, culminating in the creation of a functioning battlebot and a final written report on their project.

Through their participation in this course, the upper class students experience first hand the type of design issues and compromises that are necessary to manufacture a safe and functional product using limited resources. Additionally, the upper class students are responsible for all economic and personnel related decision-making. Upon completing the battlebot project management course, each upper class student should be able to;

a. apply basic project management skills,
b. manage a basic engineering project,
c. serve as an engineering team leader,
d. apply the design process to complete a project,
e. supervise the safe and proper use of hand and pneumatic tools,
f. review and edit working drawings,
g. understand product design considerations relative to the optimization, manufacture, and function of a product,
h. review a design log,
i. supervise the development of a formal written report by their team, and
j. orchestrate the development and delivery of a professional quality oral presentation.

Other implied objectives of the course include; to offer upper class students experience solving open-ended problems, to encourage creative problem solving, to build confidence, and to demonstrate the rewards of engineering project management.

A breakdown of the course topics and corresponding grade weighting is provided below.

Topic	Grade Weight
Project management	10%
Leadership	8%
Communication	10%
Oversee lab policies and certifications	10%
Oversee hand and pneumatic tools laboratory	8%
Oversee design process	10%
Oversee design project logs	8%
Oversee design project written report	10%
Oversee design project presentation	8%
Completion of project model (battlebot)	10%
Battlebot competition	8%

III. EF 2984, "Introductory Engineering Project – Robot"

Most of today's' freshman-engineering students arrive at college with good academic skills, but little or no mechanical know-how. The EF Division at Virginia Tech has worked to correct this experiential deficiency by incorporating hands-on activities into the freshman-engineering curriculum and encouraging mentoring programs. Overall, the students have met these efforts with great enthusiasm. The freshman level battlebot course expands these efforts by exposing the students to the complete design/build life cycle of a real project while increasing peer interactions and mentoring from upper class students. The freshman students start with a problem definition provided by their team leaders. The team leaders then assign individual (or group) tasks and responsibilities for the various project phases, and the students must report their progress to their team leaders, not the professors. By following this chain of command hierarchy, the students get a taste of real team-based project work.

The freshman students are exposed to and use numerous engineering principles and tools while being actively involved in design and economic related decisions. The students learn brainstorming, optimization, decision matrix use, and teamwork skills. Also, the course provides opportunities for the students to use the computer-aided design (CAD) software (Inventor) and engineering analysis techniques taught in the required "Introduction to Engineering" course for freshmen engineering students. As with the complementary EF 2974 course, the EF 2984 course reflects today's engineering and design community team and task-based approach to problem solving.

Upon completing the battlebot project course each freshman student should be able to;

a. apply the design process,
b. safely and correctly use selected hand and pneumatic tools,
c. produce working drawings,
d. understand the basic engineering principals behind remote control operations, motion mechanisms, and structural elements,
e. specify basic product design considerations dealing with optimization, manufacturing, and function,
f. create a functioning battlebot,
g. properly maintain a design log,
h. develop a formal written design report,
i. develop and deliver a professional quality oral presentation, and
j. work effectively as a member of an engineering team.

Other implied course objectives are; to offer students open-ended problems, engage and encourage student creativity, increase the mechanical know-how of students, and to show how fun and rewarding engineering can be.

A breakdown of the course topics and corresponding grade weighting is provided below.

Topic	Grade Weight
Course Introduction	5%
Knowledge of lab policies	5%
Hand and pneumatic tool certification	10%
Design process	10%
Design project log	5%
Team design project laboratory	35%
Design project written report	10%
Design project presentation	5%
Functioning battlebot	10%
Battlebot competition	5%

IV. EF 2974 / EF 2984 Course Schedule

Both courses are designed and executed to maximize the hands-on time that students spend in the laboratory. No structured class lectures are given, though specific reading and study assignments are stipulated in the course syllabus. In addition, the students are provided with self-paced tutorials and given timetables for their completion. The first ten minutes of the laboratory period are devoted to answering student questions, giving spot quizzes, and performing other necessary administrative functions. Once the preliminaries are completed, the team leaders assume control of their teams and immediately begin project work. The goal is to foster a true project environment that allows each student to assume responsibility for his or her own learning and for the success of their teams' project, while still accomplishing the course teaching objectives.

At the first class meeting, all students are given a course syllabus, laboratory rules, and operating instructions for the hand and pneumatic tools to be used. The first several class meeting are devoted to creating teams, certifying the students on the use of tools, brief discussions of the available equipment, and pop quizzes on the assigned reading. During these lab periods, the teams are also issued their team tools and equipment, and allowed some group time for brainstorming and getting to know one another. By the start of the third class period, the students are certified on the use of the tools and the majority of the remaining class time is devoted to work on the design and construction of the battlebots.

A mid stream review of each team's project is conducted during the seventh class meeting. During this review, the project managers are required to present to the instructors an update on their progress thus far and to convey their plan for completing the project on time. The freshmen team members are responsible for a brief oral presentation of their project vision and their roles in making the vision a reality. The design log of every student is subject to review at any point throughout the semester. The Final written reports and oral presentations of both teams are due on the thirteenth lesson.

The climax of these integrated courses is the team competition, consisting of three battlebot events. The first event is a timed exercise where teams navigate their battlebot through a maze. The second is a push / pull competition where team battlebots compete in an exercise similar to a Sumo rope pull. The third and most energizing event is the battlebot fight to the finish. This final activity not only creates lasting memories but also validates team design accomplishments while also surfacing associated flaws.

V. Equipment Requirements

The teams require access to certain tools and materials in order to complete their projects successfully. The students are charged a $30 lab fee that covers the expendable materials used during the semester. The total costs for course tools and materials can be kept surprisingly low by taking a practical approach to design and construction. The student starting point for their battlebot motive force and chassis are two radio-controlled vehicles purchased from Radio Shack. Each team is also issued a work bench/tool chest that is stocked with nuts and bolts, a hammer, screwdrivers, hacksaw, and other hand tools. In addition, each team

is give access to numerous common-use tools such as pneumatic nibbler and shears, angle grinder, and electric drill. These simple tools and some readily available sheet metal and angle iron can be used to manufacture a battlebot chassis from the reconfigured radio-controlled cars. In fact, much of the needed metal may be salvaged from the campus scrap metal bin. Rechargeable drills are cannibalized for their motors to drive the battlebot weapons. Pop rivets and bolts are used as fasteners rather than welding so that a host of ventilation and safety issues are avoided. In general, by taking a simple and straightforward approach to the design, costs are controlled and a reasonably fearsome battlebot can be constructed by the novice teams.

VI. Documentation and Publications

The freshman students have limited, if any, experience using the engineering design process. They are given additional reading material on the engineering design process.[2] The upper class students are given supplemental material on project management.[3] Every participating student is also given copies of the laboratory safety rules and instructional guides on tool use. These documents resemble high school shop class documentation and are required reading. The information contained in these documents forms the basis for the written certification tests and in-class quizzes.

Each team is provided team binder containing supplemental instructions, reference material, and website information detailing course requirements and establishing battlebot constraints. The reference material includes several books on battlebot design and construction along with a complete set of "Battlebot" regulations.[4,5,6,7,8] This library of material serves as a basis for each team's battlebot design and build project.

VII. Use of Tools in the Design Laboratory

As mentioned previously, the majority of freshman students arrive without much knowledge or experience using hand or pneumatic tools. To assure the tools are used safely and properly, all students working in the lab must pass a written and a performance test for each tool. Students are provided reading material on safe and proper tool use, must sign a waiver that releases the university from liability, and then must pass a simple written test on each tool before moving on to the skills test. During the skills tests, each student is given a short practical task that requires the use of laboratory tools. The instructors supervise and check off the safe and competent use of each tool by the student. Any written or skills test that is not successfully completed must be repeated by the student. Once a student has completed the series of written and practical tool tests, they are certified to use the tools within the laboratory.

The instructional documents and written tests mirror a high school shop class type of documentation. The students are also provided with copies of the instructions that come with each tool. All written tool certification tests require a score of 100% to pass. For large classes, the certification process can be time consuming and instructors may wish to consider an additional meeting time to accomplish student certifications without impacting design time in the lab.

VIII. Conclusions

This parallel and interactive course design does accomplish the course objectives. The courses provide an open-ended design and project management opportunity for both freshman and upper class engineering students. Each student learns to participate in and contribute to a team effort. Students learn and apply the design process and project management processes through a fun and creative experience. They are also introduced to and use common tools and equipment. The university benefits by providing a hands-on learning environment with minimal resources and cost. All in all, the courses provide a win-win situation for both the students and the university.

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