A Multidisciplinary Team Design Project for First-Semester Engineering Students and Its Implementation in a Large Introduction to Engineering Course

Kenneth W. Hunter, Sr.
Tennessee Tech University

Abstract

Numerous studies of freshmen engineering programs have promoted the use of team design projects and hands-on activities in an effort to provide freshmen with more engineering content in the early semesters, a better connection to the profession of engineering, and an opportunity to express their creativity through the design process. This paper describes a team design project that was successfully implemented in a one-credit introduction to engineering course by a single faculty member with approximately four hundred first-semester engineering students divided among fifty-one design teams. The project was based on the design of a vehicle similar to the United States Army's Armored Vehicle Launched Bridge (AVLB) and included requirements for conceptual design, engineering graphics, engineering analysis, engineering economics, and construction of a working prototype. The scope of the project was broad enough to include design issues relevant to most disciplines of engineering, thereby providing a multidisciplinary element. The realistic basis of the project provided opportunities to discuss related global and societal issues, such as the need for rehabilitation and replacement of various forms of national infrastructure. Although this project was more challenging than previous ones, the number of teams delivering a working prototype increased significantly. Factors that may have contributed to the improved results include the placement of the project in the first half of the semester and the availability of a dedicated workshop for the freshmen students. The results of a student survey regarding teamwork and other project issues are also included.

1. Introduction

All of the major NSF-funded engineering education coalitions (e.g., ECSEL, Foundation, Gateway, SUCCEED) have recommended the infusion of design, teamwork, and active learning concepts into freshman engineering curricula. Likewise, numerous studies of freshmen engineering courses and programs have promoted the use of team design projects and hands-on activities in an effort to provide freshmen with more engineering content in the early semesters, a better connection to the profession of engineering, and an opportunity to express their creativity through the design process. A challenge, however, has been to implement these concepts with large numbers of students when constrained by limited class time and personnel resources. This paper describes a team design project that was successfully implemented in a one-credit introduction to engineering course by a single faculty member with approximately four hundred first-semester engineering students divided among fifty-one design teams.

2. BE 1210 – Introduction to Engineering

BE 1210 - Introduction to Engineering is a typical overview course that exposes freshmen engineering students to a variety of engineering topics including engineering design, teamwork, and a team design project. It is required for all engineering majors at Tennessee Tech and most students take it during their first semester.

The team design project has always been a popular part of the BE 1210 course. Several modifications designed to improve the team design project, as well as the course, have been attempted over the past few years. The project now requires conceptual design, engineering graphics, engineering analysis, engineering economics, and construction of a working prototype. The integration of these topics into the design project resulted in a savings of one class period, which was then used for additional discussion of the design project. Based on the results of a study focused on teamwork issues in BE 1210, a brief teamwork lecture and a fifty-minute team-building workshop are now conducted prior to the design project.[1] These activities have resulted in improved team performance.

Because BE 1210 is required for all engineering majors, design project topics must be carefully selected so that the project scope is broad enough to include issues relevant to most of the engineering majors offered at Tennessee Tech, which are chemical, civil, computer, electrical, industrial, and mechanical engineering. This selection criterion provides a multidisciplinary element to the project, as well as ensuring that the topic will be of interest to most of the students. Topics with a realistic basis are also preferred as they provide opportunities to discuss related global, societal, and ethical issues. Other important criteria for topic selection include ease of implementation for the instructor, cost of implementation, cost to students, and the availability of support facilities, such as labs and shops. Past topics have included the design of trebuchets, sumo cars, hill-climbing vehicles, and rope climbing devices. While few of these topics meet all of the desired criteria mentioned above, they are all easy and inexpensive to implement, require minimal lab/shop support, and are relatively inexpensive in terms of student costs.

During the fall semester of 2003, there were three sections of BE 1210 with a total enrollment of 401 students. Limited faculty resources and a lack of teaching assistants resulted in a single faculty member teaching all three sections. This scenario has been the norm for this course for many years. In an effort to again improve the team design project experience for the students, while ensuring ease of project implementation for the lone faculty member, three course modifications were made:

- A new design project topic, the Basic Engineering Vehicle Launched Bridge (BEVLB), was selected. This topic met more of the desired criteria than previous ones.
- The team design project was scheduled during the first half of the semester. This was done to build student interest and enthusiasm for the engineering profession from the start, to avoid overloading the students with major projects at the end of the semester, and to give the faculty member more time to grade the project reports.

- A small shop facility to support the construction of working prototypes was established and opened to the students during afternoon and night hours. Four workbenches, several other worktables, a good selection of hand tools, a drill press, a band saw, and a bench grinder were available. Student workers were used to keep the shop open, enforce safety policies, and offer limited assistance.

3. The Basic Engineering Vehicle Launched Bridge (BEVLB) Project

The BE 1210 team design project selected for the fall semester of 2003 was based on the design of a vehicle similar to the United States Army's Armored Vehicle Launched Bridge (AVLB), which consists of a tank chassis fitted with a folding bridge and a hydraulic bridge deployment mechanism.[2] Figure 1 shows an M60A1 AVLB with the bridge in the loaded position. Figure 2 shows the vehicle deploying the bridge. The bridge allows military units to quickly cross narrow streams, road craters, ditch-type obstacles, and partially damaged bridges. The bridge can be deployed and retrieved without exposing the crew to hostile fire. The new project was called the Basic Engineering Vehicle Launched Bridge (BEVLB) Project.

Figure 1. AVLB, bridge loaded.

Figure 2. AVLB, bridge partially deployed.

A clear advantage of the BEVLB Project was that it met most of the selection criteria previously described:

- The topic is real and current. It provides an excellent case study for class discussion of related global and societal issues, such as the need for rehabilitation and replacement of various forms of national infrastructure. The existing inventory of AVLB's represents a weakness in the United States military infrastructure. The vast majority of the existing AVLB's are based on 1950's technology, have an average age of 25 years, have never received a major upgrade, are slower than the other combat vehicles they are used to support, and carry bridges that must be operated at reduced span distance and crossing speed when supporting the M1 Abrams main battle tank. Although a newer model of AVLB has been released, the M104 Wolverine Heavy Assault Bridge, it will not be produced in sufficient quantity to replace the older models. A plan to recapitalize the older models is ongoing and includes significant upgrades to the chassis and new bridges with longer spans and higher load ratings.
- The topic can be used as an introduction to ethical issues, including the personal ethics related to working on weapons systems.

- The design of this type of vehicle requires input from a variety of engineering disciplines and fits the multidisciplinary requirement of the BE 1210 design project. The magnitude of the design effort also helps justify the use of rather large teams. Table 1 lists some of the specific design issues related to each engineering discipline.
- The project is easy and inexpensive to implement. The test setup required for teams to demonstrate their working prototypes consisted of two tabletops covered with carpet, a few metal weights, a small wood board, and two small bar clamps.
- The cost to construct a working prototype, estimated to be $120, is quite reasonable when divided among the members of a team.

Table 1. BEVLB Project Content by Engineering Discipline

Engineering Discipline	**Relevant Design Issues**
Chemical	Material properties and selection
Civil	Bridge design, structural design of chassis
Computer and Electrical	Electric motor and battery selection, battery pack design, control system design
Industrial	Controller ergonomic design, human-machine interface issues, quality control functions, economic analysis, overall project management
Mechanical	Chassis and drive system design, bridge deployment mechanism design, control system design

The BEVLB Project was presented to the student design teams with the following task statement:

Each team of seven to eight students will design a Basic Engineering Vehicle Launched Bridge (BEVLB), prepare and submit required design documentation, construct a working prototype, and demonstrate that the prototype meets required criteria.

The required design criteria were:

- Overall dimensions must not exceed 12-inches in length and 7-inches in width. This includes the vehicle, launcher, and bridge in the loaded position.
- All power for propelling the vehicle and deploying the bridge must be provided by commercially available batteries carried on the vehicle and/or the bridge. Only size AA, C, D, and 9-volt batteries are permissible, but any number or combination of those batteries is permissible.
- All vehicle functions, including bridge deployment, must be remotely controlled. Both radio and wired controllers may be used. Wired controllers must include a minimum of 8-feet of cable between the controller and the vehicle.
- The vehicle, with bridge loaded, must be capable of making both right and left turns with a maximum turning radius of 9-inches, measured at the vehicle centerline.
- The bridge must span an open gap of 10-inches and support a concentrated load of 5-pounds applied at the center of the bridge deck.

- Prototypes may not incorporate the use of compressed gases, chemical or flammable propellants, or other materials or mechanisms that could create a hazardous situation. Pointed projections and sharp edges are prohibited.
- Drive trains and radio control systems from commercially available toy vehicles are prohibited, unless the components have been completely removed from the toy vehicle and combined with other components not related to the toy vehicle.

The required design documentation, due two weeks after the beginning of the project, was worth sixty percent of the project grade and included:

- A one-page graphical representation on ledger-size paper containing enough detail that it is obvious how the vehicle functions. The graphical representation could be a sketch, drawing, computer-generated plot, or other graphical representation of the design.
- A one-page written summary presenting the key design features of the vehicle and the reasons for incorporating the features into the design.
- A cost analysis documenting the cost of all materials and parts used in the vehicle and labor costs to assemble the vehicle.
- A bending stress analysis of the main longitudinal members of the bridge structure.

The construction and demonstration of the working prototype was worth forty percent of the project grade. Bonus points were awarded for recovering the bridge to the loaded position after crossing it, unique aesthetics, innovative design features, high quality construction, successfully spanning gaps of 15-inches or 20-inches, successfully supporting loads of 10-pounds or 15-pounds, having a loaded vehicle height of no more than 7-inches, and negotiating a series of obstacles (steps, hills) on the approach to the gap. The working prototype was due two weeks after the design documentation was submitted.

4. BEVLB Project Implementation and Results

The students in each section were randomly assigned to teams of seven or eight. All sections received the following classes:

- One fifty-minute lecture on general engineering design topics, including the engineering design process, concurrent engineering, and unintended design consequences.
- A brief lecture on teamwork and a thirty-minute team-building workshop that included a socialization activity, a team charter activity, and a team initiative.
- Two fifty-minute lectures on the project and related topics, including AVLB's, electric motors, circuits, batteries, controllers, drive systems, bridge design, material properties, and simple bending stress analysis.

The project culminated with an in-class demonstration of each team's prototype vehicle. This event was open and several students invited friends and family to attend. The atmosphere was quite friendly and the teams cheered for each other even when things did not go as planned. Past projects frequently culminated in a competitive event that tended to suppress the sharing of ideas and information between teams. In this case, the teams seemed to compete against the design criteria, not each other. Newman and Amir made similar observations during a first-year aerospace design project at MIT.[3]

A noticeable difference between this project and previous projects was the increase in the number of teams constructing a "successful" prototype. In this case, "successful" implies a prototype that could function well enough to satisfy the majority of the operating requirements in the design criteria. In previous projects, 50 to 70 percent of the teams would typically produce successful prototypes. Forty-six of the 51 teams participating in the BEVLB Project (i.e., 90.2 percent) produced working prototypes. This result is especially significant considering the increased difficulty of the BEVLB Project compared to previous projects. The BEVLB prototypes also displayed a wide range of very creative solutions to the problem. Figures 3 and 4 show a typical BEVLB prototype.

Figure 3. BEVLB, bridge loaded.

Figure 4. BEVLB, bridge partially deployed.

5. Post Project Survey Results

A student survey was administered after the conclusion of the design project and before project grades were posted. An initial evaluation of the survey yielded the following results:

- 72.2 percent of the students rated their overall experience with the BEVLB project as positive or very positive.

- 52.2 percent of students rated the BEVLB project as better or significantly better than their experience with other team projects. 21.1 percent rated it as about the same.

- Most of the students' written concerns focused on teamwork issues rather than the actual project. The most common complaints involved lack of commitment on the part of some team members, unequal distribution of work, scheduling difficulties, and lack of effective communication between team members.

- With regard to the availability of dedicated shop facilities to support the design project, 90.6 percent of the students reported the shop facilities had either a positive or significant positive impact on their project results. The most common recommendations regarding the shop facilities were to increase the size of the facility, increase the available hours, and add more tools and machining capabilities. Based on shop sign-in logs, over 250 of the 401 students enrolled in BE 1210 worked in the shop at least once during the project. Over 80 percent of the teams used the shop.

- With regard to the scheduling of the design project during the semester, 26.7 percent of the students favored placing the project near the beginning of the semester, 48.9 percent near the middle of the semester, and 24.4 percent near the end of the semester.

6. Closing Observations

Initial evaluation of the post project survey indicated the majority of the students perceived the BEVLB Project as being a positive experience. The number of teams producing working prototypes also exceeded that of previous semesters' projects. Because of the multiple changes that were introduced, the impact of the individual changes is uncertain. Potential positive impacts included the following:

- The nature of the project topic provided both a greater and more clearly interdisciplinary challenge, which the student teams accepted and solved with great creativity.
- The shop provided a valuable resource for the construction of working prototypes. It also encouraged more hands-on participation, experimentation, and testing.
- Scheduling of the project in the first half of the semester generated early enthusiasm and eliminated conflicts with assignments in other courses due at the end of the semester.
- No increase in faculty workload was observed and the early scheduling of the project benefited the instructor as well as the students.

This project will certainly be used again in the future. Additional analysis of the post project survey, including evaluation of gender differences, may also be conducted.

Bibliography

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Biography

KENNETH W. HUNTER, SR.
Kenneth Hunter is currently Associate Professor and Director of the Basic Engineering Program at Tennessee Tech University. He received his B.S. and M.S. degrees in mechanical engineering from Tennessee Tech University and has over 28 years of engineering experience, including positions in academia, industry, the United States Army, a government laboratory, and his own consulting business. He is a registered P.E. in the State of Tennessee.