First Year Engineering Experience with Project Centered Research

Barbara E. Mizdail
The Pennsylvania State University – Berks College

Abstract

In the 21st Century, our educational institutions exist in a climate of accelerating global change. This climate necessitates that engineers understand a systems approach and function as integrators in a complex global society with ever increasing and demanding problems to solve. Engineering has a direct and vital impact on the quality of life for all people, locally and globally. Consequentially, it is incumbent upon our educational systems to see that the education of future work forces must include a problem solving systematic approach to projects. Such an approach will produce engineers capable of imparting knowledge integrated from a holistic view and applying a systems approach to practical solutions. The old principles where an engineer understands a single system and attempts to assemble the resulting systems from that perspective are no longer viable. Engineers of the 21st Century will face issues in an exploding environment, expanding their vision from local issues to worldwide concerns while interacting with businesses globally.

Learning how to be productive contributors in our continuously changing world is the challenge of the engineering student. To facilitate in this learning, the Pennsylvania State University – Berks College has offered engineering and engineering technology students a project centered learning experience in their first year. One approach was to allow students to identify their own projects, providing them with an understanding of project phases and importance of documentation. A second innovative approach was to form student teams to work directly with faculty researchers on current research projects. Faculty presented their research projects and students selected those that they would like to work on. Although faculty research does not traditionally employ first year students, this approach set out to raise awareness of current research and engage the students for future involvement in research projects.

The results of both approaches provide the basis of this paper. It includes a view of the selection of projects reflecting the concerns of today's students for the environment, positive feedback from research faculty for student contributions with existing projects, and an awareness of the capabilities of students at this first year level.

The First Year Experience

A first year experience for incoming students is not a new concept to higher education. For more than twenty years, colleges and universities have contrived and implemented ways to support student success during the critical first year. The majority of all colleges and universities offer a first year seminar course or experience to their first year entering class. First year experiences can increase the probability of students successfully completing their first year of study, which leads to the increased probability of graduation. This, therefore, is a critical component to the retention of students. One of the most commonly cited statistics of higher education is that the majority of students that begin never graduate. There is significant national research available on the most effective ways to positively engage first time students to college life, including small class size, direct involvement of faculty, academic skill development and psycho-social development.

Observance of the first year seminar experience at The Pennsylvania State University – Berks College has shown that the engineering and engineering technology students come already equipped with many of the skills lacking in the general population of first year students. The engineering students usually have acquired good academic skills, study skills, library skills, critical thinking and problem solving skills, and are comfortable in the use of technology. They come to college eager to put their skills to use as "an Engineer". What they usually lack is an understanding of the question, "What is engineering"? Taking a discipline centered approach to the first year seminar was the first step in tailoring the first year seminar to engaging engineering students and affords the opportunity to provide them with the answer.

Providing the student with the broad understanding of the engineering profession, while focusing on enhancing their study skills and test taking skills, can be accomplished with traditional methods using textbooks and lectures. This is how the first year seminar was run in previous years. However, three years ago a different project centered approach was initiated for the engineering first year seminar. Now the students would be able to learn about engineering, as well as have an engineering experience. Findings have shown that students engaged in technology project learning achieve higher than those taught using traditional lab experimentation.[8] The students involved in projects demonstrated a linkage between learning principles and their applications, and achieved higher grades. Students were allowed, with the Instructor's approval, to choose their own projects. The Instructor provided ideas for project topics, but the students took it from there and chose project topics of interest to them. Today's engineering students are especially aware of environmental and sustainability issues. It was this genuine student interest that led the Instructor to the second approach to the first year experience which involved specific research projects with faculty researchers, and will be discussed later.

First Approach – Project Centered Engineering First Year Seminar

To begin the course, students were given a Time Management Seminar. The college experience comes with new opportunities and distractions that can take up a student's time. This is one of the critical areas that all students coming from the high school environment must deal with. All incoming first year students at The Pennsylvania State University – Berks College are provided with yearly planner notebooks to record assignments and activities. Some engineering students come equipped with personal electronic planners. Although all incoming students may choose to sign up for a Time Management Seminar, the Advising Officer that gives these seminars agreed to visit the classroom and give the engineers a seminar tailored to the generally more conservative, focused, and goal oriented engineering majors. At the appropriate time, discussions of the use of timelines for projects and project management were entered into the course. Engineers working in industry depend on timelines for tracking projects. For the capstone senior design courses, the students are required to complete timelines. By introducing the concept to the first year students, they will be ahead in their appreciation of this project management tool.

Next in the course, the students were provided with the following concept, that of engineering as an applied science. Scientists unlock the secrets of the universe, but it is the engineers that work diligently, often behind the scenes, to apply the science and improve our society's quality of life. In high school the concepts of science and engineering are often blurred. After all, engineers and scientists share the same basic fundamental education which includes subjects in math and the sciences. As new scientific discoveries are made, continuous learning is important to the engineering profession. Demands, along with constantly changing technical information, drive the necessity for engineers to keep current and continuously learn. Learning how to be productive in our changing world is challenging. Today's students have experienced rapidly changing technology in their lives, and are able to grasp the concept of continuous learning. At this point in the course, it was also helpful to introduce the students to the different engineering disciplines and technical societies linked to the various disciplines which provide activities for continuous learning[10], i.e.: ASME mechanical, IEEE electrical, AIMBE biomedical, AAEE environmental, etc. An assignment to research an engineering discipline of interest to the student is encouraged. Then ask the student to visit the website of the technical society supporting that discipline. The following questions can then be posed to the students.

1. What is the technical society all about?
2. Tell about a meeting/conference/or event that the society is holding that would be of interest to you.
3. What are membership benefits?
4. What is the cost to join as a student, and will you consider joining?

As was previously stated, the students were provided with a list of potential subjects for engineering projects, and encouraged to suggest others. The subjects suggested have included projects connected to active student engineering clubs; involvement with member companies of the IAC, Industry Advisory Council; and other campus activities. The following Table 1 contains a list of subjects chosen by students for their projects over the past three years.

Table 1. Examples of First Year Engineering Seminar Projects

2007 Projects

1. Society of Automotive Engineering, SAE, Advertising, Marketing and Sponsorship for Baja student competition
   - Business aspects of supporting entering a student competition
   - Develop in C++ programs for storing sponsor information and formatting letters.
2. Test Track Build and Mapping
   - Design, build and map a test track to simulate a Baja vehicle competition track
   - Develop rules for safe operation of Baja vehicles on campus
3. SAE Baja Vehicle Mechanical Design
   - Splash Shield design
   - Suspension A-Arm design
4. Art & Engineering
   - Structures designed, built and entered into campus art show
5. Robotics Club

- Formation of a student Robotics Club to pursue entering student competitions

2008 Projects

1. Alternative Energy Resources
   - Design of motion power generators
2. Sustainable Communities in underdeveloped countries
   - Choosing materials for construction projects
3. Tractor design
   - Alternative fuels
4. Lighting for new campus building
   - Solar powered ambient lighting
5. Biodiesel fuel
   - Develop small scale biodiesel manufacturing utilizing resources available on campus in the form of waste fryer oil
6. Hybrid powered vehicle
   - Continuation of project for testing donated vehicle
7. Duel fuel systems for city buses
   - Investigate secondary fuel systems for buses to cut down on emissions
8. SAE Test Track
   - Continuation of project to develop track to simulate competition and test vehicles

2009 Projects

1. Design a website for a student engineering club
   - Updating dated website with current website techniques and information
2. Design Iphone/Ipod touch applications
   - Create applications (apps) specific to our campus
3. Lighting for new campus building
   - Continuation of project for solar powered ambient lighting
4. Hybrid powered vehicle
   - Continuation of project determining what parts are needed and the cost
5. Solar powered lithium battery charger
   - Design, build and test
6. High powered rocket construction
   - Design, build and test
7. Art and engineering
   - Aesthetically pleasing structure built from recycled and natural materials
8. Robot Competition
   - Design of VEX Robots
9. SAE Baja performance team
   - Develop performance tests and recording data
10. SAE Baja Test Track
    - Continuation of previous project with addition of a hill climb for testing gearing
11. Construction of an Ozonator
    - Proposed design for water sanitation

The next step was to introduce the budding engineers to Project Management, specifically the design and management of technically oriented projects. The four phases of a project were outlined as follows.[1] It is worthy to note that these phases have also been adopted in the Introduction to Engineering Design classes and provide consistency in terminology for the first year engineering students.

1. Phase I - Conception Phase
2. Phase II - Study Phase
3. Phase III - Design Phase
4. Phase IV - Implementation Phase

Now was when the discussion of timelines was put to use. Students were shown examples of project timelines, and asked to make Gantt Charts. This is a very useful planning tool used in industry. Those students familiar with MS Project were encouraged to use the software. Courses in MS Project are offered on campus and are optional to our students. Two interim report dates during class sessions were scheduled in the semester for students to update the Instructor and fellow students on their progress, including addressing any obstacles. The interim report dates are often referred to as “project milestones” in industry. During these report-out sessions, the students on other teams share comments and advise, while the Instructor facilitates. The Final Report dates are also added to the timeline. During team meetings, students are expected to maintain timelines adding the critical components outlined in each project phase.

Other in-class activities during the semester included a session in the library. This was arranged specifically to allow research during the Study Phase of the projects, and also served as the traditional indoctrination to the library. The Research Librarian was provided a list of the students’ projects, and she tailored her presentation to applicable materials. She focused on the technical resources available through the extensive Penn State University library system. She offered assistance in navigating the system, and also offered that reference librarians can be resources for the future. Another in-class activity revolved around how to prepare for and present a successful oral presentation. All students will be taking a required communication course, but this is usually offered during the sophomore year. Therefore, this activity helped prepare the students for communicating their ideas and preparing to report on their accomplishments. The final reports, both oral and written, were graded on the topic, content, logical sequence of presentation, and creativity. The final report reflected the students interest and efforts, which ranged from extremely interested and “really into it” to “just enough to pass”. Although the later proved the exception, the earlier observations were reinforced that students who choose engineering come to college eager to put their skills to use as “an Engineer”

Second Approach – Linking Research to the Project Centered Engineering First Year Seminar

Building on the success of introducing engineering projects to first year students, a second approach was introduced which appeared to serve two purposes. The first was student involvement with faculty researchers, and the second was interest in undergraduate research. The idea was to ask faculty researchers to involve teams of first year students in their active research. Several questions were posed by the faculty, including:

1. Can first year students be capable of understanding complex concepts?
2. Will the time involved interfere with the researchers' already busy schedule?
3. What are the benefits?

Attacking first the question of benefits, by engaging first year students in research, it is hoped that they will develop an interest for continued involvement in undergraduate research. There is a continued interest in increasing undergraduate research. Prompted by the criticisms of the influential Boyer Commission, that universities were failing to bring undergraduate students into their active research, there has been an increase in initiatives in the United States to make undergraduate research part of institutional research.[9] Questions 1 and 2 will be addressed in the conclusions.

For this approach, a class of twenty first year baccalaureate bound engineering students was chosen. These students are pursuing of a four year baccalaureate degree in Electro Mechanical Engineering Technology. They will be at the PSU - Berks campus for four years. It is therefore conceivable that they are available for future undergraduate research during those four years.

Since this was the first attempt to involve faculty researchers, it was decided to approach the engineering faculty and those researchers involved in some way with engineering research. Five faculty researchers agreed to be involved: two Electrical Engineers, one Mechanical Engineer, one Agricultural Economist, and one Kinesiologist. The five Researchers were asked to come to one of the first class meetings to introduce themselves, and their areas of research to the students. Students were then asked to rank the top three researchers that they were interested in working with. The Instructor took these requests and assigned four students to each Researcher, attempting to match them with one of their three choices. There were five teams of four students established. Students were then asked to meet in their teams, introduce themselves, exchange contact information, and plan times to meet. No re-balancing of the groups was necessary.

At this point it is interesting to note that this class had taken the Myers-Briggs Type Indicator test, and received their four preferences. One of the practical applications of the MBTI is for understanding these preferences in support of better teamwork.[1] Differences can lead to quite different value structures and communication styles, which can hamper mutual understanding and cooperation. Further study is needed to determine how influential this exercise was in influencing the team dynamics. However, the students were asked to share their preferences, keeping in mind how the innate personality preferences could enhance the tasks forthcoming. After discussing ideas for a project, the next step was for the teams to meet with their Faculty Researcher.

In class the students were introduced to the four phases of a project; Conception, Study, Design and Implementation, (Used in the first project based approach, and outlined in Appendix A). As with the previous approach, in-class exercises included time management, timelines, library research and oral presentations. After scheduled team meetings with their Faculty Researcher, the teams were asked to report-out in class twice during the semester, and they were given in-class time to work on their projects. They were given the freedom to use that time as needed to go to the library, meet with their Faculty Researcher, work on prototypes in the mechanical or electrical lab, or visit places of business that could enhance their knowledge of the projects. They were also encouraged to read and reference their Faculty Researcher's publications. The

Final Reports were presented during a special session, held in a room in the Student Center and complete with refreshments, where faculty researchers and other interested faculty and students were invited to observe. Photographs of students and their hardware and prototypes were taken, and an article about this innovative approach for the first year experience for engineers is being prepared for the College's "Research" magazine. Presently, several of the projects are being considered for inclusion at a local regional undergraduate research conferences.

Real research and engineering happened! All the faculty researchers expressed satisfaction with the output from the five student projects. The students rose to the occasion in most cases presenting substantial contributions to the research efforts. Opportunity to include discussions on ethics presented itself, especially in tracking the project budgets. Each team was provided a $100 budget. Several teams built prototypes. The mechanical and electrical lab supervisors also spent time with these novice team members - novice in that they had not yet had courses that familiarize them with the mechanical and electrical equipment and lab capabilities at the college. Provided in Table 2 below is a list of the five research projects topics, as well as the students' initial descriptions submitted at the onset of the projects. Please note that some these projects are proof of concept research, based on, but not limited to published research which is referenced.

Table 2. First Year Engineering Seminar Research Projects

---

1. Energy Harvesting Research Project

The purpose of our project is to find a way to efficiently harvest energy from everyday human activities. The idea is to capture a small amount of energy from a simple activity like opening and closing a door. A door can be opened and closed a few hundred times a day so the potential of harvesting a descent amount of energy is significant.[3]

2. LED Lighting Research Project

This project will test and compare different lighting systems. We intend to compare several lamps, including incandescent, CFL (fluorescent), and LED (light emitting diode). We will build a test fixture and measure the light output. Cost will also be considered.[4]

3. Knee Brace Research Project

The knee is one of the most commonly used joints in a human body. When a knee is injured, there are many possibilities for rehabilitation. The rehabilitation method that the Research Team has selected to test is the knee brace. Most knee braces are designed to reduce lateral motion of the knee. The design that the team will be looking at is made to not only reduce lateral motion, but also reduce muscle activity around the knee. The team will test the subjects wearing the knee brace by comparing data that is collected from standing up to sitting down on a chair. The team will then attempt to make improvements with the design in hopes to create a more efficient knee brace.[5]

4. Biomechanics Research Project

Biomechanics is the application of mechanical principles to living organisms. This includes bioengineering, the research and analysis of the mechanics of living organisms and the application of engineering principles to and from biological systems. For our project we are studying the ball and socket joints in the human body. Using magnets we are going to try to model a frictionless ball and socket joint.[6]

5. Sustainable Communities in Underdeveloped Countries

As part of our research project we will explore the different water harvesting systems that would be available to use in Kenya, Africa. There is a desperate need for better water harvesting systems in Kenya with people dying daily from lack of water and pollution in the water. The two systems that we will focus on are roof rain harvesting and sand dams.[7]

Conclusions

This paper has outlined procedures to gain broad and reaching benefits of incorporating engineering projects and undergraduate research in the first year experience. In the refined second approach, students were given the opportunity to participate in active research projects and experience performing as engineers. They shared in the excitement of attacking challenging issues, while learning about putting to use the latest technologies. By building a relationship with a faculty member through participating in their research, the students learned that they can be contributors at the undergraduate level. They were encouraged to continue this relationship and maintain interest in performing undergraduate research while pursuing their baccalaureate degree. Also, faculty researchers expressed satisfaction with the level of understanding demonstrated by the first year students. Time commitment for the faculty was minimal amounting to an hour per week on average during the semester. Importantly, all five faculty members declared their time had been spent on a worthwhile endeavor and agreed to future involvement with the first year research program.

The students were involved in projects with issues of both local and global scope. They were exposed to current intellectual debate, and witnessed how engineering contributions can systematically affect resolution of complex problems. The student evaluations of all of the f the project centered first year engineering seminars validated the high level of excitement, interest and satisfaction demonstrated during the experience. The interaction between the student team members and the faculty researchers as reported by the faculty was positive, but some challenges arose. Current beginning engineering students are quick to question past practices. They have seen such grand technological changes in their short lives and are rather over eager to put their skills to work. At the first year level the students lacked the math skills to back up some of their observances; however, their ability to set goals for the projects demonstrated the desire for practical solutions. Overall the approach was a success. Both faculty and students stated that they benefited from the experience, and the faculty agreed to continue working with future classes. In fact one of the student teams is presently scheduled to present their work at a regional undergraduate research conference. This approach of involving first year engineering students in active research with faculty will encourage these students to stay involved and make a difference as they pursue their engineering education. It also serves as a foundation for their continued interest in serving as productive contributors in our continuously changing world. These first year engineers demonstrated that they are up to the challenge.

Appendix A: Four phases of Technical Project Management[2]

Phase I - Conception Phase

Activity 1: Select the Project

a. Choose a Project – Brainstorm with others to choose a project
b. Select one of the proposed projects or suggest another project. Come up with a concept first formulated in the mind of one or more persons. It may be a concept that can be designed or developed immediately, or it may require further study.

Activity 2: Organize a Team

a. Choose 2 – 4 class members/Team

Activity 3: Initiate conception Phase Documents

a. Write a Project Description (100 word abstract) of what the project is and why it is worth pursuing.
b. Prepare preliminary specifications/objectives.
c. List tasks
d. Start to formulate a schedule (key dates/key milestones).

e. Complete the planning for the next phase of Work….Study Phase.
f. Planning Ahead →

    Who will be responsible for the work?
    What is to be accomplished and by whom?
    When is it to be implemented?
    Where is it to be performed?
    How will the performance of the project be controlled?

g. Prepare a Gantt chart

    Week 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

    Conception Phase________
    Study Phase --------------date________
    Design Phase --------------------------date______
    Implementation Phase ---Reports

The Gantt chart or bar chart is the oldest and most frequently used chart for plotting work activities against a time line. Gantt charts show how long a project will take when tasks that are independent of each other are performed simultaneously. The most common reason to use a Gantt chart is to monitor the progress of a project.

Phase II - Study Phase

Activity 1: Organize the Study Phase Work

a. Review the Who, What, When Where, Why and How questions from the Conception Phase Effort.
b. Develop the Study Phase Details. The schedule should connect together the start, performance and completion of each task.
c. Organize the Team into small groups.
d. Assign each group a set of tasks to do. Use your Gantt chart to track tasks.

e. Ask the following questions to assist in this process:
    - What are the necessary skills for performing the Study Phase tasks?
    - Which of the team members' skills apply to completion of the Study Phase?
    - What/Who is available outside of your Team to assist you?
    - Who will supervise the work and make sure the Team is on schedule?

Activity 2: Establish the Ground Rules
a. Expand on the objectives of the project that you agreed upon during the Conception Phase.
b. How will documentation of the project be compiled?

Activity 3: Study Solutions
a. Devise approaches for technological improvements to be made.
b. Investigate whether potential solutions have been previously devised.
c. Avoid investigating solutions requiring excessive expenditure of time or money.
d. Simpler solutions may keep the project on track and avoid failure.
e. Determine risks and trade-offs.
f. Gather and evaluate information.
g. Select and plan your path of action.

Phase III - Design Phase

Activity 1: Organize the Design Phase Work
a. Review the Study Phase effort.
b. Develop Design Phase details.
c. Organize teams and assign design tasks.

Activity 2: Select the Solution Details to be implemented
a. Study potential implementation solutions.
b. Contract sources that will be needed to implement.
c. Determine actions necessary.

Activity 3: Document the Design Solution
a. Prepare any specifications.
b. Prepare any drawings, bill of materials, instructions and procedures.
c. Refine tasks, schedules and budgets.
d. Document the design/course of action, and reasons for its choice.

Activity 4: Prepare for the Implementation Phase Work
a. Review the Design Phase results.
b. Verify availability of Implementation Phase resources
c. Plan the Implementation Phase

d. Prepare the Implementation Phase report.
e. At this phase of your project you should be able to:
  - Define the purpose and goal of the project.
  - Explain the tasks involved in the Design Phase and the activities or steps through which these tasks are performed
  - Describe the role of the team leader in the design phase
  - Provide a Gantt chart of your activities
  - Describe the documents that should be prepared to keep you on task and record your progress
  - Explain why human factors need to be considered in project management
  - Determine when the Design Phase will be complete, and the Implementation Phase initiated

Phase IV - Implementation Phase

Activity 1: Obtain all the resources necessary for the project implementation as were defined in the Design Phase.
Activity 2: Review all the project documentation.
Activity 3: Allocate tasks to the Team to complete the project.
Activity 4: Prepare the deliverables of the project.
Activity 5: Revise, Review, and Deliver the Final Documentation.
Activity 6: Report on the project, including offering suggestions for improvement or continuation.

After completing this engineering project, you should be able to:

- Identify management functions, organizational issues, and different styles.
- Select people to staff a project based on skills needed and possessed.
- Gather and organize information necessary to monitor and control projects.
- Realize the importance of documentation.
- Understand the components of project control.
- Communicate ideas.

References

1. Myers, Isabel Briggs with Peter B. Myers, *Gifts Differing: Understanding Personality Type*. Mountain View, CA: Davies-Black Publishing, 1995.
2. Angus, Robert B., and Gunderson, Norman R., and Cullinane, Thomas P., *Planning, Performing, and Controlling Projects*, New Jersey, Prentice Hall, 3rd edition, 2003.
3. Litwhiler, D. H. and Gavigan, T. H., "Energy Harvesting: Measurement and Analysis of Swing Doors," Journal of Engineering Technology, Vol. 25, No. 2, pp 26-31, fall 2008.
4. Lee, Shiyoung,"Application of a Software Configurable Digital Servo Amplifier to an Electric Machine Control Course," The International Journal of Modern Engineering, Vol. 9, No. 2, pp. 49-58, Spring/Summer 2009.
5. Russell, D. M., & Newell, K. M., *On no-KR tests in motor learning, retention and transfer*, Human Movement Science, 26, 155-173, 2007.

6. Banafsheh Barbadi, Rungun Nathan, Kei-peng Jen and Qianhong Wu, *On the Characterization of Lifting Forces During the Rapid Compaction of Deformable Porous Media*, Journal of Heat Transfer, Volume 131, Issue 10, 2009.
7. Larson, Janelle M., Stephen M. Smith, David G. Abler and Carolina Trevelli, *An Economic Analysis of Land Titling in Peru*, Quarterly Journal of International Agriculture. 42(1):79-97, 2003.
8. Waks, S. and Sabag, N., Technology *Project Learning versus Lab Experimentation*, Journal of Science Education and Technology, Vol. 13, No. 3, pp. 333-342, Sept. 2004.
9. Boyer Commission (1998), *Reinventing undergraduate education: A blueprint for America's research universities.* Stony Brook, New York: Carnegie Foundation for the Advancement of Teaching.
10. Nicholas Basta, Opportunities in Engineering Careers, McGraw-Hill Companies, Inc. 2003.