A Capstone Experience: Putting Students to the Task

Dr. W. Larry Williamson,
Mr. Randy Winzer
Pittsburg State University
Pittsburg, Kansas

Abstract

Pittsburg State University has been teaching a “Capstone” class involving all seniors majoring in Mechanical and Manufacturing Engineering Technology since being accredited by TAC/ABET. (Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc.) The class is a culmination of the knowledge the students have gained during their tenure at PSU. In 1996 the two professors in charge of the class decided to use the NASA sponsored human powered moon buggy competition (http://moonbuggy.msfc.nasa.gov/) as a common project for the students to accomplish the goals and objectives of this class. In 2002 some of the students from the Electronics Engineering Technology Program’s “Capstone” course decided to design and build a system to gather telemetry from a student built moon buggy.

Introduction

Pittsburg State University in 2003 will celebrate 100 years of providing learning opportunities to students. Pittsburg is located in the southeastern corner of Kansas and is centrally positioned near larger cities such as Wichita, KS, Kansas City, MO and Tulsa, OK. The University was founded in 1903 as a Manual Training College to prepare teachers for the manual arts and trades, including homemaking. The fall 2002 enrollment for PSU was 6,700 students, including both undergraduate and graduate students. International enrollment for PSU is approximately 470 students representing 47 countries. Four colleges are located within the University, one of which is the College of Technology. The College of Technology has an enrollment of 1600 students in four major departments. They are Graphics and Imaging, Technology Studies, Technical Education, and Engineering Technology. The largest department within the College of Technology is the Department of Engineering Technology, which consists of the following technical areas:
Mechanical, Manufacturing, Electronics, Plastics, and Construction. This department is also the largest on campus with 540 students. All five programs within the Department of Engineering Technology have been accredited by TAC/ABET (Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc.) since 1979.

TAC/ABET re-accreditation of all five technical areas took place during the fall of 2001 using the newly adopted criteria often referred to as the TC2K “outcomes assessment” model. The criteria addresses the issue of “how to measure” what is done in the learning process to ensure the program is meeting the established goals of the technical area, the department, the college, and the University. The goals of the program are to be derived from input from a variety of sources, including industry and/or industrial advisory committees. The TC2K accreditation process requires that the program document how they are measuring their progress towards these goals. The accreditation process is not a traditional “bean counting” or accounting process as used in the past. The TC2K accreditation process is similar to an ISO: 9000 or the new ISO/TC: 16949 registration process used by industry. The process is also similar to the guidelines found in the Malcolm Baldrige National Quality Award. Simply stated: 1. State your goals and objectives, 2: Show how you are meeting your goals and objectives, and most importantly 3: Show how you are measuring what you are doing to meet the stated goals and objectives.

TAC/ABET requires each program to have a “Capstone” class or experience, which brings together all of the students’ acquired knowledge from their college and/or university tenure. This class is traditionally taken during the student’s final year. The Mechanical and Manufacturing “Capstone” experience at PSU addresses nearly all of the items found in the “a thru k” elements of criterion 1. (1) These engineering technology programs have elected to combine the two technical areas into one class (having two parts) in which the “Capstone” experience occurs. The mechanical engineering technology majors traditionally have more design emphasis; whereas the manufacturing engineering technology majors traditionally have more process emphasis in their respective programs. To be successful in today’s industry, one has to be able to “design for manufacturing”. Bringing student teams together with both mechanical and manufacturing backgrounds provides an environment in which students learn through the strengths and weaknesses of each other. The class is team taught by the senior professors from the two technical areas, thus bringing into the class the expertise of both design and manufacturing.

The PSU mechanical and manufacturing “Capstone” experience is broken into two classes -part one is conducted in the fall semester for one hour credit and part two in the spring semester for two hours credit. In the fall semester the students are placed into a team of four or five students based upon each students’ background, strengths, and weaknesses. During this time the student teams develop a concept, develop a model of their concept, test some of their concepts, and develop complete working drawings needed for the manufacturing phase. Analysis of material strength requirements is a must. Calculations must be shown and reasons given for material selection. Manufacturing issues are considered in all concept phases of the student work. Each team provides formal reports, both written and oral, to management (the professors) throughout both semesters. Each team must prepare a budget and a program plan for all segments of their project. Student teams are allowed to follow their own ideas even if the professors think it may not work. Learning from failures at this level is often a better educational tool than being
successful.

In the spring semester, the student teams work in the various PSU laboratories building their projects. No work is allowed without manufacturing process procedures. Consideration of quality control issues is also expected from each group. Each team member is expected to contribute to the project. The final project is then evaluated to see if the objectives of the project have been met.

The Project

The project chosen the past seven years for the PSU mechanical and manufacturing “Capstone” experience is for each team to design and build a Human Powered Moon Buggy. The idea of building a human powered moon buggy came from the NASA sponsored Great Moon Buggy Race held in Huntsville, Alabama each year since 1994. The race is modeled after the original moon buggies built at the Redstone Arsenal, taken to the moon in the lunar module and used by the astronauts to travel the lunar surface. For this moon buggy contest, human power was selected as the mode of power in place of the batteries used to power the original moon buggies.

There are two divisions in the contest, one for high schools and one for colleges/universities.

The primary purposes of the contest are to encourage students to learn more about math, science, working together and having fun. The contest may also help students select a career in the aerospace industry. The Great Moon Buggy Race is a two-day contest; contestants come from all over the USA and Puerto Rico. PSU does not build moon buggies to win but rather as an educational experience for the following reasons:

**Figure 1**: Apollo Lunar Rover

There are two divisions in the contest, one for high schools and one for colleges/universities.
The project was selected because it has allowed the student teams to take an idea from its conception, provide engineering analysis, design the detail parts, manufacture the parts, and test the final product in one major undertaking.

Cooperative industry projects selected as a “Capstone” experience could lack the startup and closeout sequences. These projects are often underway prior to a student arriving and continued well after a student leaves. This causes the element of project completion to be missing, resulting in a lack of closure to the educational experience.

Many of the cooperative industry projects will not be done in a team environment.

Using the human powered moon buggy as a project for the “Capstone” class allows the students to work with many components within a complex system.

Project Requirements

NASA provides the contest requirements for all vehicles; additionally the professors in charge of the class have imposed specific course requirements. The NASA requirements are: (6)

1. It must be human powered by both a man and women.
2. The propulsion system cannot have any device, which can be used for energy storage.
3. It must fit into a 4 foot by 4 foot by 4-foot volume constraint.
4. It must be carried by the two student drivers for a distance of 20 feet in the unassembled condition.
5. No part of the body can be within 15 inches of the lunar surface (ground).
6. The vehicle must be able to have a 20-foot turning radius.
7. The moon buggy cannot be any wider than 48 inches in the assembled condition.
8. The moon buggy will have dust abatement devices (fenders), a simulated high gain antenna, simulated battery boxes, a simulated TV camera and a simulated control panel.
9. There cannot be any device used to prevent the moon buggy from tipping over such as an outrigger.
NASA requires the human powered moon buggy to be assembled and traverse over a track, which represents the lunar surface of the moon. Both events are timed then added together to produce a total contestant time. In the past, there have been fifteen obstacles to cover in the race. Each obstacle has time penalties assessed to the team should the moon buggy fail to make it though the obstacle. Prizes are awarded to the first three places in both divisions. First prize in the college/university division is $3500 to be used for a team of up to six individuals and their advisor to attend a shuttle launch at the Kennedy Space Center in Florida. Pittsburg State University has taken first place twice, 1999 and 2001. PSU has built over 25 moon buggies in the past six years and is building four more this year. Each school is allowed to bring two moon buggies. Since four are being built this year, there will be a “race-off” conducted on the PSU campus to determine who will represent PSU at the contest in Huntsville, Alabama.

The material selection used for the human powered moon buggy is to be determined by those building the vehicle. The number of wheels, their size, and the type of power system are also left up to the participants. Typically, a moon buggy will have three or four wheels powered by the use of bicycle parts with frames made of everything from plastic to titanium.

The PSU course specific requirements are:

1. The moon buggy must have a suspension system.
2. Some part of the vehicle must use a casting.
3. Some part of the vehicle has to have a composite part.
4. The ideal goal for the weight of the moon buggy without drivers is 100 pounds.
PSU believes the weight issue is important since Kansas has major aerospace manufacturers that employ many of our graduates. Weight goals also contribute to the students calculations related to strength to weight ratios.

Photo showing Pro/E stress analysis of moon buggy suspension A-arm. Photo removed in order to meet AS EE Board of Directors mandated 2 mega-byte file size limitation for all papers that are loaded into the CAPS system. (7) Contact the authors to obtain a full version including color images.

Figure 3: Pro/E Stress Analysis (2)

Each student enrolled in the PSU mechanical and manufacturing “Capstone” class is required to contribute $100. The two professors in charge of the class also contribute $100 to each team. For a team of five students, having a starting budget of $700 is just that—a starting budget. Each team can seek additional funding and in-kind help from industries, etc. In 1999, one team used some one-inch titanium tubing PSU had received from Boeing for their moon buggy frame. Cessna Aircraft in Wichita provided an in-kind donation to the team for the bending and welding of the titanium frame totaling $15,000. This team did not place due to the failure of parts unrelated to the frame of the vehicle. The large expenditure on the frame was inconsequential to the overall success of the team.

Team Selection and Makeup
The manufacturing and mechanical “Capstone” team selection technique has been undergoing a process of evolution starting with the course’s inception in 1993. The two major professors teaching the course have discovered a variety of factors contribute to team success including but not limited to: team size, personality of the teammates, student’s major (Mechanical vs. Manufacturing), student course loads, and total number of hours worked by each teammate.

The ideal team size ranges between four to five students. Experience indicates that more than five students results in having some students doing the majority of the work and a few along for the ride. Less than four students creates an excessive workload in order for the students to finish the project during the two-semester time frame. Student workload for the fall semester is expected to be approximately 6 to 8 hours of work per team member outside of class time. This time is spent in the design and analysis stages of their project. During the spring semester each teammate is expected to devote 12 to 15 hours manufacturing and testing their vehicle. While students consider this to be an excessive amount of time for a total of 3 credit hours over the two semesters, course evaluations generally indicate positive experiences. A majority of students say after graduation, and even after years spent in industry, that this was one of the best experiences they had during their educational career. Several have commented how this helped prepare them for the challenges of working in industry today.

Based upon the ideal team size, the faculty in charge of the course determine the team member selection. Prior to the fall of 2002 the selection was done before the first class via a review of the strengths and weaknesses of each student by the two professors responsible for the course. Since both mechanical and manufacturing engineering technology students comprise the course, a mixture of majors should be included on the team. The programs are small enough that each student typically has taken more than one class from each of the faculty in charge of the “Capstone” course. Over a coffee and donut session the strengths and weaknesses of each student are discussed; every effort is made to make sure each team contains a mixture of talents on the team. No consideration is given to having a team of overall weak students or a team of overall strong students.

Beginning in the fall semester of 2002, a new twist was added to the team selection process. Each student supplies a note to management (the responsible faculty) indicating the course load they are taking during the semester and the number of hours working outside of the university, such as a job. Team selection now includes these additional factors.

2001-2002 Capstone Class

The 2001-2002 “Capstone” class for the PSU mechanical and manufacturing engineering technology students was the first time the professors in charge of the class imposed an ideal weight of 100 pound or less for the vehicle. PSU had won the University division Great Moon Buggy Race in Huntsville in April of 2001. Second place went to New Jersey State University. The winning time difference between first and second place was 4 seconds. PSU had built a traditional moon buggy having four wheels, four-wheel drive, and in-line seating for the drivers.
This team used a “recycled” titanium frame from a moon buggy built in the 1999-2000 class. Air shocks were used to reduce the weight of the moon buggy. Although, the frame was made from titanium and used lightweight air shocks, the total vehicle weight was 180 pounds. The second placed team from New Jersey had a three-wheeled moon buggy, used aluminum for the frame, and used composite wheels. The weight of their moon buggy was 80 pounds. Based upon what had been done by other schools, the professors in charge of the class implemented a 100-pound goal for future PSU moon buggies.

As mentioned previously, Pittsburg State University does not build moon buggies for the sole purpose of winning. The moon buggy is a student team project in which the students’ start with a concept and work towards the finished product, having done the work mechanical and manufacturing engineers perform in industry today. Winning is secondary to learning. In the fall of 2001, the four new PSU “Capstone” teams viewed videotapes from the past contest races showing many ideas from other schools and universities. Many new ideas were generated by the student teams on how to build a moon buggy to weigh 100 pounds or less without drivers. One particular group who called themselves “Team Gearhead” adopted the three-wheel idea for their moon buggy concept since it was apparent a three-wheel vehicle, having one less wheel, would weigh less than a four-wheel vehicle. The students also knew a three-wheel vehicle had taken second place the year before, only four seconds behind the PSU winning time.
Wire frame model of human powered moon buggy. Photo removed in order to meet ASEE Board of Directors mandated 2 mega-byte file size limitation for all papers that are loaded into the CAPS system. (7) Contact the authors to obtain a full version including color images.

Figure 4: Concept Sketch One (2)

3-D color rendering of human powered moon buggy. Photo removed in order to meet ASEE Board of Directors mandated 2 mega-byte file size limitation for all papers that are loaded into the CAPS system. (7) Contact the authors to obtain a full version including color images.

Figure 5: Concept Sketch Two (2)
Mechatronics: Introduced into the Project

Pittsburg State University does not have an official “Mechatronics” program but the department of Engineering Technology does cooperate between its’ various programs. Collaborative student projects are encouraged, as is cross awareness within the various disciplines. The following working definition has been developed for making our students more aware of the diversified nature of today’s industry. ‘Specialists in Mechatronics play an important role in today’s industrial environment. These professionals know how the sometimes-virtual world of electronics, interfaces to the very real world of mechanical systems. They can install a new machine, make necessary calibrations to electronic controls, and modify software as required. The resulting union of electronics and mechanics requires that the student be accomplished in a variety of fields including robotics, pneumatics, hydraulics, transducers, communications, control systems and software development. These individuals truly are like a “jack of all trades.”’

During the fall semester of 2001, one of two professors in charge of the “Capstone” course for the Electronics Engineering Technology (EET) area approached the two professors teaching the Mechanical and Manufacturing “Capstone” class with an idea and proposal. The professor’s proposal was to attach strain gages to critical frame components and the suspension. These strain gages would provide input into a transmitter, which would send an output signal to a remote location. The idea of cameras showing the ground, the drivers, etc. and a Global Positioning System (GPS) was also discussed. The students working on this phase of the project would be EET majors. The major goal was to measure the actual stress being placed upon the frame and suspension system. Having real data from actual testing conditions would be an important asset in determining safety factors for future projects. The electronics majors would work independently of the mechanical and manufacturing “Capstone” students since the controls could be easily installed on any one vehicle to be determined in the spring semester. The control system to be built could take the place of the simulated control panel NASA required for the moon buggy competition. This is the first time three technical programs within the Department of Engineering Technology would work on one major project, that being the human powered moon buggy. Mechanical and manufacturing students would work on design and manufacturing issues, while the electronics engineering technology students would work on integrating electronic sensors into a moon buggy. Mechatronics yes, but the faculty at PSU only considered it an opportunity to work together within the department on a common student project, with students from all three programs gaining knowledge from the experience.

Team Gearhead

This group of “Capstone” students, as mentioned earlier, elected to design a human powered moon buggy having the following characteristics:

1. The moon buggy would have three wheels, two in front and one in back, which would control the steering.
2. A side by side rider configuration was selected.
3. It would have an aluminum tubing truss frame.
4. Composite wheels would be used.
5. Maximum speed of 20 MPH would be their goal.
6. The frame and seats would support a load of 500 pounds.
7. Air shocks would be used to reduce weight.

Based upon the above design considerations, the team proceeded, building upon the concept model shown in Figure 5 by developing a set of engineering drawings to support manufacturing issues.

Evaluation of Mechanical and Manufacturing Students

Every effort is made to treat students in the “Capstone” classes just as they would be treated in industry. The two professors in charge of the class act as the management team and each group makes regular reports to them; no formal examinations are given. Teams are expected throughout the semester to produce management updates in a variety of formats. These reports and presentations cover such topics as design concepts, design considerations, analysis of constraints, final design, manufacturing drawings, manufacturing process planning, quality control, and testing. All presentations are video taped and accompanied by a written report. Each page of a written report indicates who has completed the work. Management has provided to each student team the report format and minimum requirements. Evaluations for the presentations are provided to the team via meetings with management and feedback is supplied at this time. Records are kept to be used during final evaluations and assigning of grades. Additionally each group provides management bimonthly progress reports documenting their individual efforts within the team. The student is to rate their contribution to the team based upon a 1, 2, or 3 scale. One is below average, two is considered average and three is above average. A policy states that a team having a rating of all 3s would be considered to be all 2s or average. Students are reminded of this prior to completing the report.

The professors in charge also record who is doing a majority of work in the laboratories and who is frequently absent or not meeting expectations. Students not contributing to the team’s efforts are identified and consulted with by the management team. Grades are assigned accordingly, consisting of possibly a D or F at mid-semester and/or an incomplete given to students who provide little or no documentation as to what they have done. Removal of an incomplete grade is based upon the progress of the student during the second semester.

The final presentation of the entire two semester’s work is done at the end of the spring semester. This presentation is given to the combined Manufacturing and Mechanical Engineering Technology Advisory Committees and other invited guest. The two advisory committee groups are provided with an evaluation form for each of the teams. This evaluation is correlated with the results from the management team.

Beginning with the fall semester of 2002, the management team consisting of the faculty
responsible for the course established a “benchmark” for each team. Previously the students always started from “scratch”, meaning no previous years reports or materials were provided to the students as a guide or an experience to learn from. For the school year 2002-2003, a previous year’s work was selected to be the benchmark for the class. All reports, drawings, and other materials were to be equal to or better than what the previous class had prepared. This material was provided in the form of a CD with all presentations, drawings, analysis, and manufacturing documentation.

The material generated by this course provides a good deal of the documentation needed to satisfy the a-k criteria of the TAC/ABET TC2K report. These two classes address almost every item found in the criteria. Additional details are available by contacting the authors.

Involvement of the EET Program

Just as the mechanical and manufacturing “Capstone” course validates its’ students abilities, the electronics engineering technology program also challenges its’ students to combine their educational experiences into a 9-month, 2-semester long project consisting of proposal and design phases. The students in electronics select their own working environment, be it individual or a team, as well as their own project. During the proposal phase the students must develop an original “electronic” device, demonstrate its marketability, test its feasibility and prove its worth. All of these activities take place according to a structured time table during the fall semester. The spring semester is spent constructing and testing the prototype, modifying the design, building the finished product and completing required documentation. The projects are judged at several milestones by the faculty, the Industry Advisory Committee to the EET program, and fellow students. Upon graduation the students have taken an idea from a mere concept to a working reality and spent dozens of hours in the laboratory practicing real skills such as software circuit simulation and troubleshooting. These skills not only make the EET graduates more marketable in and of themselves, but they also give them an air of confidence that will carry them much further in industry.

The professors in charge of the EET program’s “Capstone” experience often provide ideas for potential projects. During the fall semester of 2001 the idea of a way to gather various types of data about a moon buggy during competition was suggested as a potential project. A three-person group adopted this as their project for the “Capstone” sequence in electronics.

The group that undertook the “Moonbuggy Monitoring System” as they called their project consisted of Jaimee Bohannon, Kimberly Burton, and Doug Joseph. These students all completed the EET curriculum in May of 2002 and have moved on to either careers in industry or graduate school. Jaimee Bohannon was hired into an engineering management position with Raytheon Aircraft Company in Wichita, KS. Kimberly Burton, after a short stint as an Information Technology (IT) consultant has been employed as an avionics engineer with Cessna Aircraft Company also in Wichita, KS. Doug Joseph is completing his Master of Science degree in Mathematics from Pittsburg State University.
The system originally envisioned by the EET students was to monitor the following parameters: stress on various frame components, ambient temperature, vehicle velocity, location, and altitude via a GPS receiver mounted to the vehicle. A block diagram is shown below.

The system as shown above includes a module for collecting data from the strain gages and a temperature transducer, conditioning this data and transmitting it wirelessly to a receiver connected to a personal computer. The module also has an integrated GPS receiver that transmits location information on a separate wireless channel. The module can be seen as the small black box in the center of the figure below.

Photo showing moon buggy frame and seats with instrumentation module installed between the seats ready for competition.

Photo removed in order to meet ASEE Board of Directors mandated 2 mega-byte file size limitation for all papers that are loaded into the CAPS system. (7) Contact the authors to obtain a full version including color images.
As shown in Figure 6 the data from both the sensors and the GPS system is transmitted on separate wireless channels to a receiver module connected to a personal computer. The temperature and strain data is collected and stored in a spreadsheet on the personal computer to be analyzed later. The GPS data is used to calculate real time location, speed, and altitude information that are then displayed on an application running on the PC.

Conclusion

While originally envisioned as simply a method to promote interdepartmental cooperation between three programs, the project resulted in several verifiable results:

- The electronics students definitely gained an appreciation for the practical difficulties involved in a “real world” application of integrating electronic and mechanical systems

- While strain gages are covered in all of the programs as a laboratory exercise, this was probably the first time that students had applied them to a functioning mechanical system

Figure 8: “Moonbuggy Monitoring System” PC Application (3)

Photo showing complete Moonbuggy Monitoring System with base station laptop computer prior to competition. Photo removed in order to meet ASEE Board of Directors mandated 2 mega-byte file size limitation for all papers that are loaded into the CAPS system. Contact the authors to obtain a full version including color images.
The erratic nature of wireless data transmission was discovered first hand

Experience working with real-time A/D conversion

The mechanical and manufacturing students gained a greater understanding of the capabilities of remote sensing applications and data collection

The team saw personally how integrated sensors can complement a mechanical system

Bibliographic Information


Biographic Information

DR. W. LARRY WILLIAMSON

Dr. W. Larry Williamson is a University Professor at Pittsburg State University and teaches in the TAC/ABET accredited Manufacturing Engineering Technology program. Dr. Williamson’s involvement with International SME Engineering Technology education has helped build a solid MET program at PSU.

RANDY WINZER

Randy Winzer received his BS in Electronics Engineering Technology in 1989 and an MS in Engineering Technology in 2002 from Pittsburg State University. He has been an assistant professor with the Electronics Engineering Technology program since 2000 and currently serves as program coordinator. He has several years of
experience supporting network and computer systems for outcomes based education in public schools.