Session 1150

Teaching Engineering Fundamentals with a Project-Based Learning Approach

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Abstract

Recruiting and retaining students in the Engineering Technology area has been a major challenge to many of us in the Engineering Technology and Industrial Studies (ETIS) Department at Middle Tennessee State University (MTSU). In the Fall of 2004 the author offered ET 1840 – Engineering Fundamentals and teaching this class was a lot of fun. Topics such as total quality, engineering design process and engineering solutions were discussed drawing examples from the previous three Solaraider (MTSU's solar car) projects and the ongoing experimental vehicles program. The author served as chief faculty advisor for MTSU's undergraduate solar car teams from 1994 to 1999 during which period three 19'x6.5'x4' solar cars were built to compete in the cross country race called Sunrayce. Another ETIS faculty member is supervising the department's ongoing experimental vehicles projects such as solar bike, moon buggy and formula SAE. The ET 1840 students were encouraged to take part in one of these projects. In addition to lectures and discussions, the students were exposed to some hands-on and fun type activities. They were given an overview of 3-D modeling and an approximately ten-inch long cycloidal and straight path model was designed in their presence using AutoDesk Inventor. A few minutes later we went to the ETIS machine shop where the students could watch a rapid prototyping machine build the 3-D model out of ABS plastic. Two days later the students could hold the prototype in their hands and play with it. They were given hands-on design projects such as the egg drop contest and the path of least time (based on Johann Bernoulli's *brachistochrone* problem) without involving the details of the theory. The author received an internal grant from which a Pasco compact, hand-operated stress-strain apparatus was purchased and the students were given a demonstration of this unit. As part of their take home exam, the students worked on an alternative energy vehicle project to ease the traffic problem on MTSU campus. They were required to discuss their engineering design with reference to the ten-step process that has been presented in the textbook[1].

Introduction

Middle Tennessee State University is located in Murfreesboro and it is the fastest growing university in the state of Tennessee with approximately 22,000 students enrolled currently. Engineering Technology and Industrial Studies (ETIS) is one of the ten departments under the college of Basic and Applied Sciences (CBAS). The Engineering Technology (ET) program is growing annually at two percent while the university is growing at five percent. We have Computer, Electro-Mechanical, and Mechanical Engineering Technology concentrations in this program. We also have a pre-engineering program which enables students complete two years of course work at MTSU and transfer to an engineering school where they can receive a bachelor's degree. Additional information on MTSU, CBAS and ETIS can be obtained at http://www.mtsu.edu/, http://www.mtsu.edu/~collbas/, and http://etis.web.mtsu.edu/, respectively. There are approximately two hundred ET majors in our department but recruitment and retention have always been difficult tasks. There are numerous industries including Nissan, Saturn, Calsonic, Schneider Electric, Tennex, and Carrier situated in and around Murfreesboro. Many of our majors are adults who work full time and have families and these students are known as non traditional students. They are unable to make college education their top-most priority. Some students get jobs after joining the program and find it hard to cope with 50-60 hours of work and a full load of courses. Engineering Fundamentals (ET 1840) is required for all ET majors and pre-engineering students. It is essentially a gateway to all other ET/engineering courses and we feel it is important to initiate, nurture and maintain students' interest in engineering. The author taught ET 1840 for the first time at MTSU in the Fall of 2004 and wanted to make it more interesting with practical problems related to the engineering design process and problem solving. In addition to regular classroom lecture and discussion, some hands-on team projects such as the egg drop contest and the cycloid project were given to the students. As we know several web-enhanced instructional tools are available for better teaching/leaning and the author used WebCT extensively in teaching Engineering Fundamentals.

WebCT

A customized version of Blackboard called CourseInfo was used at MTSU from 2000 to 2002 and WebCT was adopted for its advanced capabilities as well as compatibility with the existing Student Information System (SIS) software. WebCT is much more powerful than CourseInfo and offers a variety of teaching/learning tools for both instructor and students. Course materials such as syllabus, staff information and homework problems were posted on the ET 1840 site at the beginning of the semester. Announcements regarding test dates, take-home exam due dates, keys to test problems, and contest/project information and guidelines were posted as the semester progressed. Students could drop their take-home tests in the digital drop box and the instructor could download and grade them. The electronic mail feature let students ask questions and helped the instructor answer their questions as well as send notifications and reminders to all or selected students. Grades were posted online and the students checked their grades at their convenience either at home or on campus. Video files of the egg drop contest conducted previously for the Dynamics (ET 3840) students and at other events were uploaded to the WebCT site for the benefit of the ET 1840 students. There was no disk space limitation and we could upload MPEG video files larger than 200 MB without any difficulty. PowerPoint slide shows and useful links about solar cars including races and contests, and alternative energy sources were provided on the course site. Students could obtain necessary information for their design project which is discussed in the next section. They could also get additional information related to the ongoing departmental undergraduate projects and contests such as the moon buggy and solar bike supervised by another ETIS faculty member.

Application of the Engineering Design Process

Many of our students who take Engineering Fundamentals will not have any background in college algebra, trigonometry or physics because there are no prerequisites for this course. This fact was always kept in mind while preparing projects or tests but some basic topics in mathematics and science were covered in the class. The author discussed Total Quality, Engineering Design – A Process, and Engineering Solutions in detail referring to specific cases related to the Solaraider projects. Undergraduate student teams at MTSU built three 19'x6.5'x4' solar cars (The Solaraiders I, II and III) between 1994 and 1999 for competing in Sunrayce, a cross-country solar car race sponsored by the U.S. Department of Energy and General Motors. The author had the privilege of serving as chief faculty advisor for all three Solaraider teams. It was relatively easy to draw examples and cite first hand experiences from these projects while discussing the above mentioned topics. As part of the first test the students were given a take-home team project that required them to propose an alternative energy transportation system for the MTSU campus. They had to follow the ten-step design process discussed in the textbook[1] as well as in the class and provide details. A copy of this project statements and requirements are provided in the appendix. A map of MTSU campus was provided as part of the project so that students could identify the streets and buildings referred in the problem statement. This map was provided by Publications and Graphics Services at MTSU and is reproduced in the appendix of this article. All thirty six students (with the exception of two or three) enjoyed working on this project and twelve different proposals with lots of good ideas were submitted on time. Some students went solo because of personal reasons and one older student was allowed to substitute his work-related project on the condition that he met the same requirements as the others. As future engineers/technologists our students need to know the fundamentals of design, drafting and manufacturing. An introduction to these areas with emphasis on computer applications is discussed in the next section.

Overview of Computer-Aided Drafting/Design (CADD) and Computer-Aided Manufacturing (CAM)

We teach several courses in mechanical and architectural CADD and the AutoDesk site license helps us maintain the latest software on our CADD lab computers. In the ETIS machine shop we have two rapid prototyping machines (Stratasys and Z-Core) and several CNC machines including the latest twenty-one tool station Fadal. As part of introducing the ET 1840 students to different areas of engineering, they were given an overview of 3-D modeling. An approximately ten-inch long cycloidal and straight path model (Figure 1) was designed in their presence using AutoDesk Inventor. The file was transferred electronically to the Stratasys machine and a few minutes later we went to the machine shop where the students could watch the machine build the 3-D model out of ABS plastic. Two days later the students could hold the prototype (Figure 2) in their hand and play with it rolling marbles down the cycloidal and straight paths. Needless to say they had a lot of fun finding out for themselves that the straight path is not the path of least time. During their visit the students also had an opportunity to watch the aluminum parts for a six-cylinder, radial air motor being machined on the Fadal receiving its information directly from a 2-D AutoCAD drawing. According to a survey engineers at work spend approximately twenty five percent of their time in oral and written communication such as presentation and reports.[1]

Therefore, it is essential that we include communications skills in our Engineering Fundamentals class and MS Office offers excellent tools in this area.

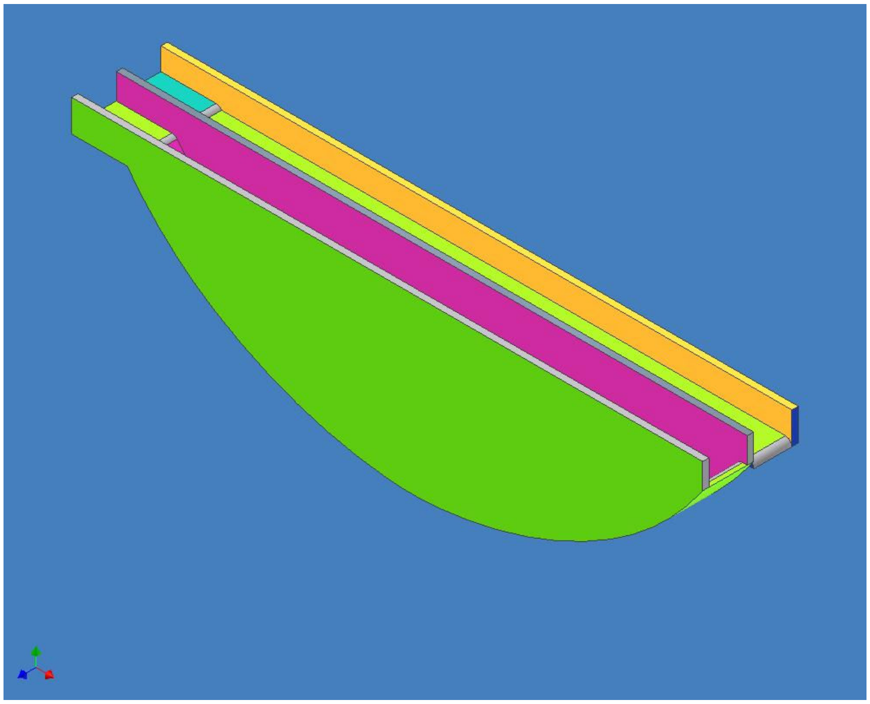


Figure 1. A cycloidal and straight path 3-D model designed using AutoDesk Inventor.

Figure 2. Prototype of the cycloidal and straight path model built on the Stratasys machine.

Basics of MS Word and Excel

The students were given a tutorial on Microsoft Word and Excel in the department's computer lab. The author guided them through important aspects of Word such as how to create subscripts and superscripts, and type equations using MS Equation Editor. Kinematics of a freely falling body was considered for illustration allowing sufficient time for the students to follow the instructor through every step. Different capabilities of Excel including computation and graphing were taught in this session. They were guided through the steps to generate the position of a freely falling body as a function of time and create a position versus time plot for 0-5 seconds in intervals of 0.1 second. At the end of this session, the students had the necessary equations and graphs for the "no parachute" case of their egg drop contest. They were given the necessary hand-written information for the kinetics of a freely falling body and asked to create the equations using MS Equations Editor and generate the position as a function of time using Excel for 0-5 seconds in intervals of 0.1second. They were required to plot two sets of graphs considering four different values of mass and drag coefficient. A quick review of Engineering Dynamics will tell us that the kinetics equation is more involved than the kinematics equation for the same freely falling rigid body. The students were given credit for this work towards the take-home part of the second test and they were allowed to use these results for the "with the parachute" case of the egg drop contest. Principles of statistics were discussed laying more emphasis on the use of Excel in computing functions such as mean, median, mode, frequency, variance and standard deviation while hand calculations were also performed for comparison. Besides learning the above mentioned computer applications they were also given opportunities to demonstrate their ability to design, build and test devices for the egg drop and cycloid projects.

Egg Drop Contest

The author has been conducting the egg drop contest in ET 3840 – Dynamics, at the Expanding Your Horizons in Science and Engineering (EYH) event for girl scouts, and for the Regional Science Olympiad participants. This contest was conducted for the ET 1840 students in an effort to make learning fun and promote team work among them. Egg drop contest guidelines were posted on the WebCT site and the students were shown MPEG videos of the previous contests to give them a good understanding of the project. These videos and pictures of the structures that survived the fall were also made available on the course site. A maximum of four students were allowed in a team and each team had to build two structures with and without a parachute using balsa wood and glue according to the guidelines. An egg had to be placed inside the structure so that it was supported at three points only.

An undergraduate senior, a graduate student and our machine shop technician (who is in charge of the CNC and rapid prototyping machines) agreed to serve as judges for the contest (Figure 3). The contest was conducted indoors at our Alumni Memorial Gym arena for consistency and to avoid cold and windy conditions. The structure and egg with and without a parachute attached were dropped (Figures 4 and 5) from a height of fifteen feet. The contest was judged considering factors such as the aesthetics of the structure, weight, location of the unit measured from the target after landing, condition of the structure and egg after reaching the ground. The students were required to compile their relevant MS Word and Excel work, do some interpolation or extrapolation of the graphs for the mass of their structure and submit it as a report. The video of this contest was posted before the final exams so that the students could watch it and upon request they could also get the MPEG file on a CD.

Figure 3. The three judges, first, second and third from right, are seen in action.

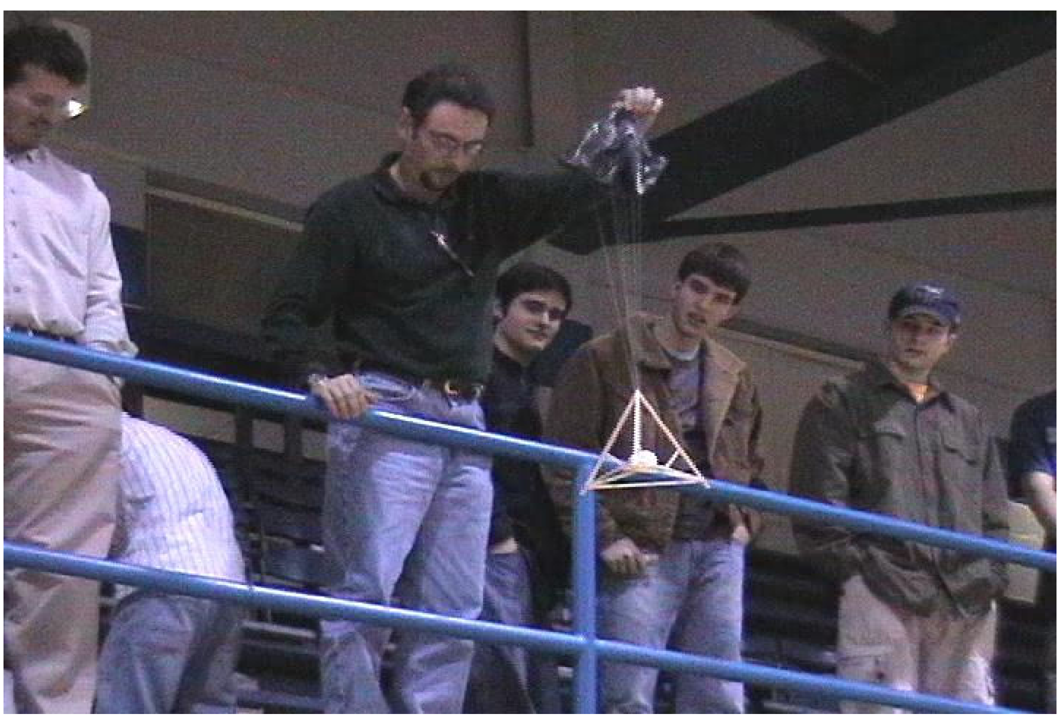


Figure 4. A structure with egg and parachute is about to be dropped.

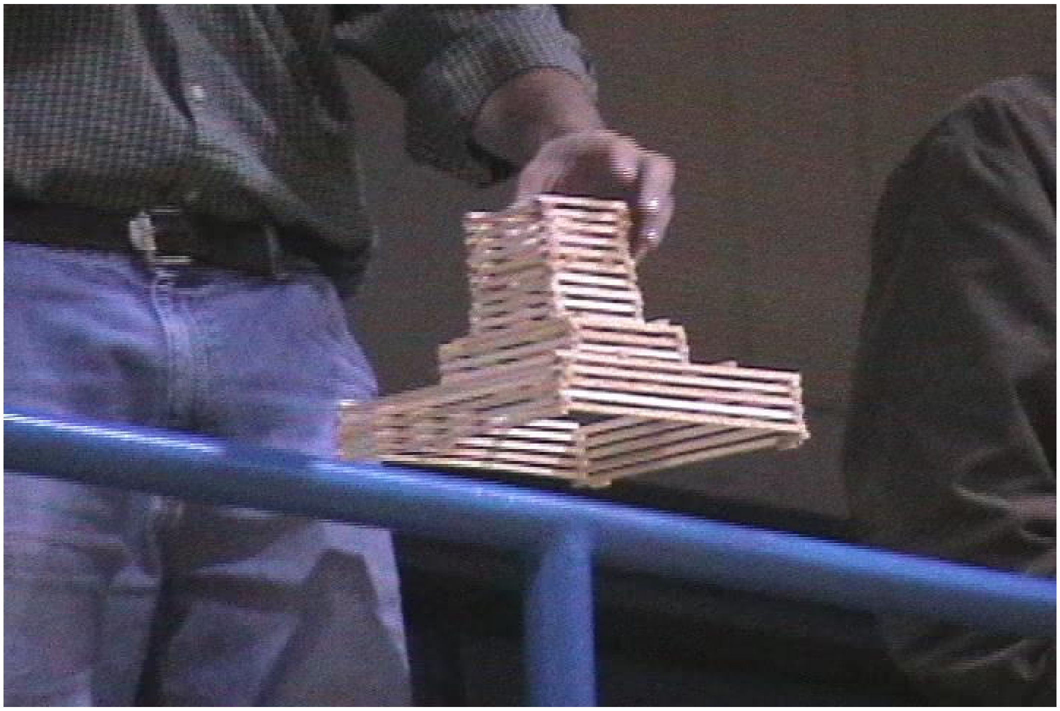


Figure 5. A structure with egg and no parachute is just dropped.

The Cycloid Project

This hands-on project is based on Johann Bernoulli's intriguing *brachistochrone* (the path of least time) problem proposed in June 1696. Additional information on this problem and about the Bernoulli brothers, Newton and Leibniz can be found at the websites, http://mathworld.wolfram.com/BrachistochroneProblem.html and http://scienceworld.wolfram.com/biography/BernoulliJohann.html.
As mentioned earlier, the author designed, built and demonstrated a 10-inch long cycloidal and straight path model. The students were unanimous in saying that the straight path would be the path of least time. But their opinion was changed after each was allowed to roll down two marbles simultaneously along the two paths. Each student team was required to build an approximately two-foot long cycloid model similar to that shown in Figure 2 but had the choice of using cardboard, plastics, Styrofoam, sheet metal or plywood. Historical information on the cycloid [2] was briefly discussed in the class and posted on the WebCT site. It included how Johann Bernoulli posed a problem about a curve of least descent and his brother Jakob solved it, and Leibniz and Newton also solved the same problem. The mathematical treatment of this problem[3,4] was also posted on the course site purely for the students' information with a note saying that they would learn more about the theory in Dynamics (ET 3840). Step by step instructions were posted on the WebCT site for constructing a cycloid graphically and building a model similar to that shown in Figure 2. Student teams enjoyed displaying and repeatedly demonstrating their cycloid model on the day of the egg drop contest and Figure 6 shows a unit built by one student team.

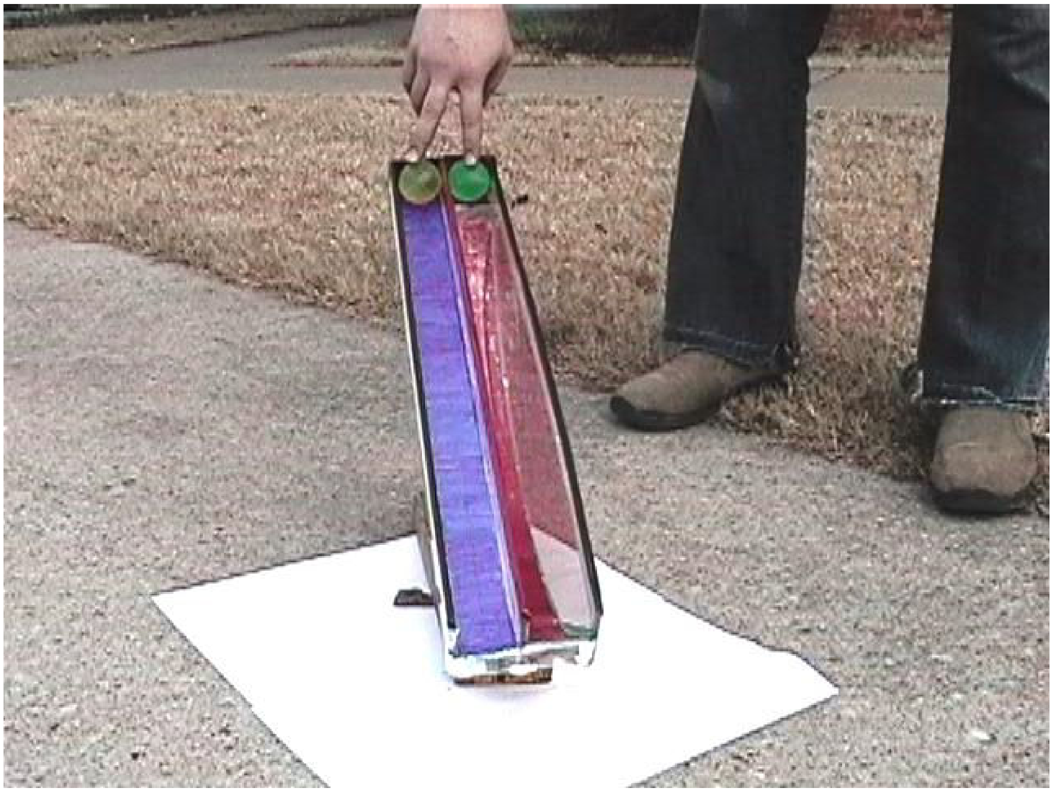


Figure 6. The cycloidal and straight path model built by one ET 1840 student team.

The PASCO Stress Strain Apparatus

Principles of Statics, Strength of Materials and Electricity were discussed briefly to generate sufficient interest in the students. The author purchased from an internal grant a stress-strain apparatus (Pasport model) made by PASCO to demonstrate the stress-strain relationship, calculation of the Young's modulus and material failure. This unit (Figure 7) which measures 10"x7"x5" is much smaller than that demonstrated at the 2004 ASEE Conference and Exposition. It came with a PowerLink interface (6"x6"x1"), DataStudio software and thirty identical specimens made of different materials. The apparatus arrived late due to various reasons and therefore, we could not calibrate it and make additional specimens on our CNC machine well before the final exams. Therefore, the initial objective of letting each student run the experiment, break a specimen and get the first hand experience could not be achieved. However, the working of the apparatus was demonstrated to the entire class.

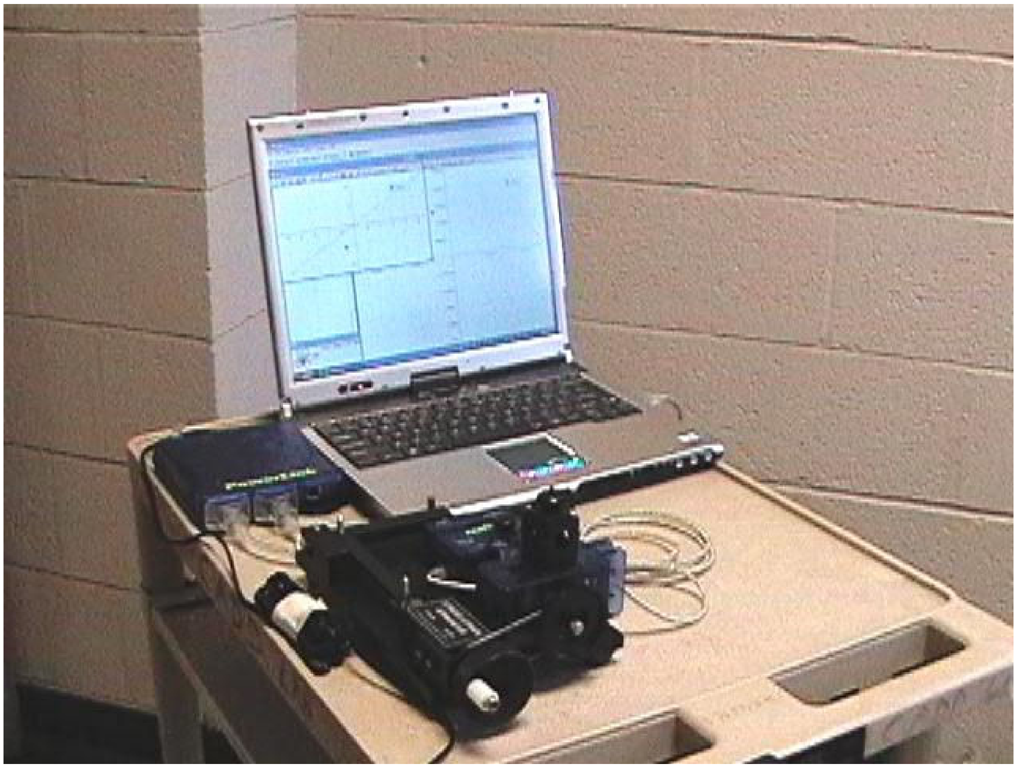


Figure 7. The PASCO stress-strain apparatus and PowerLink.

Conclusions

It was a lot of fun teaching ET 1840 – Engineering Fundamentals and the informal feedback from the students indicated that they enjoyed taking this class. Their participation in the discussion of Total Quality, Engineering Design Process and Engineering Solutions was very good. The two hands-on projects which carried 22% towards the final grade not only gave them an opportunity to be creative but also helped improve their grades. The two tests including the take-home and in-class parts contributed 56%. The author downloaded student scores from WebCT site to MS Excel and computed the percentage for each student with and without the hands-on project scores. This quick test indicated that several students who actively participated in the classroom discussions, asked intelligent questions and showed a lot of promise made a lower grade without the hand-on projects score considered towards their final grade. There is still scope to improve this course with some hands-on and fun type activities in the electrical/electronics area. This year our colleagues in the Computer Engineering Technology area agreed to arrange such lab activities but could not carry them out due to schedule conflicts. We are planning to resolve this issue by next Fall and also improve upon the stress-strain experiments. We have a 3-D scanner in the department and plan to use it to measure the dimension off the specimens supplied by PASCO so that additional specimens can be reproduced using our Fadal CNC machine. The author intends to include the demonstration of the 3-D scanner as part of the ET 1840 lab activities for the Fall of 2005. In October, 2004 we formally requested Nissan Motor Manufacturing Corporation that is located about six miles from MTSU to conduct a hands-on workshop on lean manufacturing for our ET 1840 students. So far the company has not responded and hopefully it will be able to entertain our request in 2005.

As mentioned earlier ET 1840 was taught in the fall of 2004 and this article was submitted in the first week of January, 2005. In addition to preparing lecture notes, a significant amount time was spent in designing and conducting the hands-on and other related activities. This was done while teaching a full load of courses, and carrying out research and service activities. Therefore, there was no time do any type of evaluation to measure the outcome or effectiveness of the techniques discussed in this article. However, the author intends to carry out such tasks in the fall of 2005. The project-based techniques presented in this article may not be unique but they definitely address our major objective of retaining undergraduate students in engineering/technology and offer some means to achieve it.

Appendix

Department of Engineering Technology and Industrial Studies

ET 1840 –Engineering Fundamentals	**Fall 2004**	**Test-1**
(B. S. Sridhara)	Design project	(Take-home part)

You might have noticed that the MTSU campus is getting congested because of students and faculty walking from one class or building to another and several automobiles driven in and out of campus all at the same time. This situation may become more serious as the university grows further. Let us consider the following proposal as a solution to the problem on hand with reference to the MTSU campus layout shown on page 2.

- Several huge parking lots will be built in the vacant area on campus adjacent to Scarlett Commons and Campus Recreation Center bound by Rutherford Boulevard. Please see the attached campus plan.
- All dormitories excluding Scarlett Commons will be moved to the above mentioned area.
- Everyone including students, faculty, staff, administration and visitors will be asked to park their cars in the new parking lots.
- Access to the new parking lots and all dormitories will be provided from Rutherford Boulevard.
- No automobiles other than maintenance, mail delivery and guided tour vehicles will be allowed to park anywhere but at the new parking lots.
- People can commute between the new parking lots and their classes and/or offices by riding on the RaiderExpress busses during the peak hours such as 7:30-8:30 a.m., 1:30-2:30 p.m., and 5:30-6:30 p.m.
- During the other hours only alternative source energy vehicles will be used to provide transportation. These vehicles will be able to carry 1-6 passengers and the waiting time should not exceed 5 minutes at any time or place.

Your task is to discuss the design process of such a vehicle that utilizes an alternative energy source by applying the 10-step approach discussed in your textbook and in the class. A typewritten, printed report should be submitted on or before Thursday, October 14. The body of the paper should be at least four pages long excluding figures, tables and photographs. You need to follow the guidelines provided in the textbook (section 2.11.2, pages 116-118). Also, cite your references including the Internet website addresses under the section, Bibliography. For consistency you need to follow the following format for the cover page.

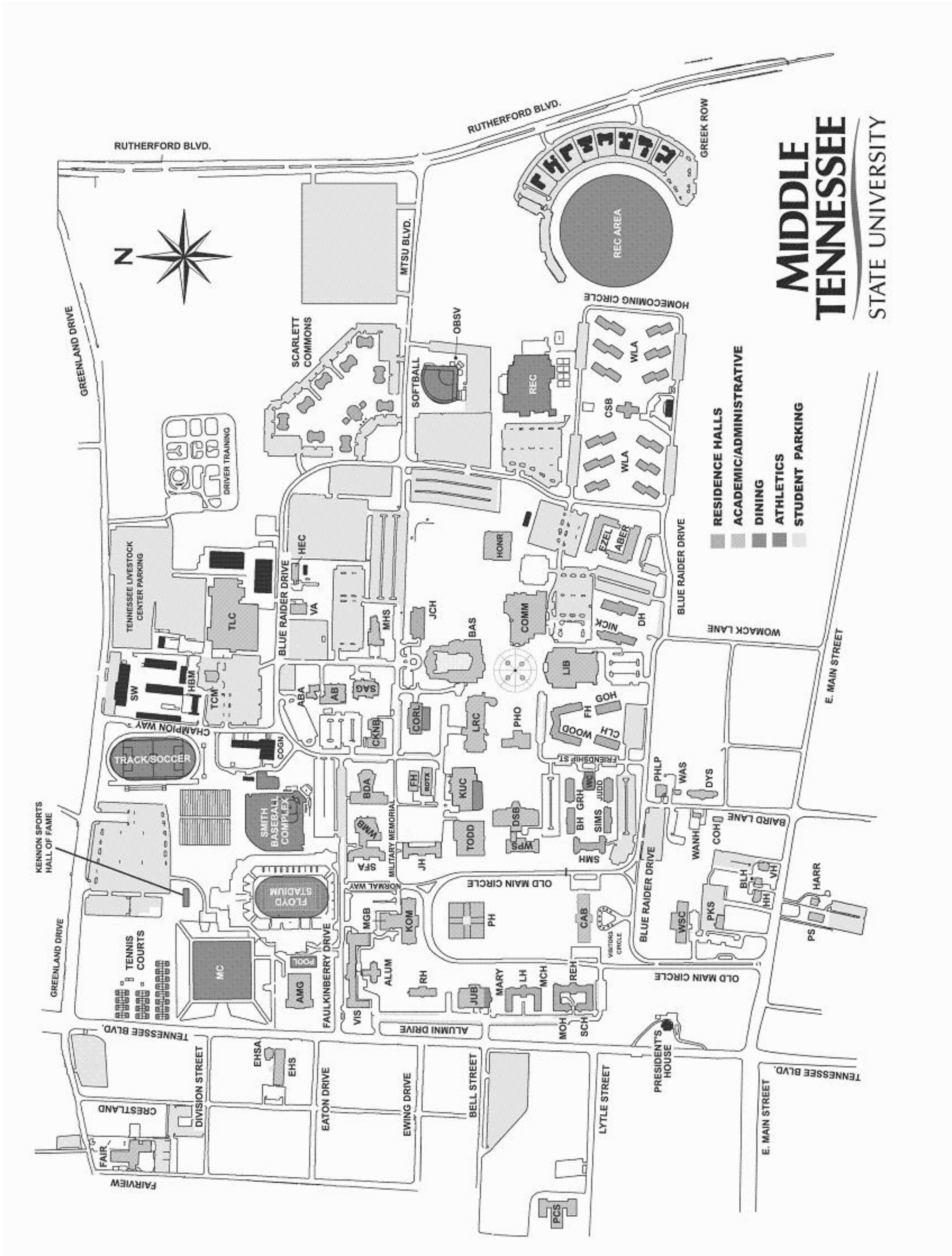
ET 1840 – ENGINEERING FUNDAMENTALS
TEST 1
DESGIN PROJECT
(Title)
TEAM

LEADER *(optional)* *(list responsibilities/contributions)*

TEAM *(list all names)* *(list responsibilities/contributions for each team member)*

DATE *(semester, year)*

MTSU Campus Layout



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