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MET Senior Projects as a Means of Developing Laboratory Experiments and Equipment for Course Labs

Prof. Craig Durwin Engle, Purdue University Calumet

Craig D. Engle is clinical assistant professor of Mechatronics Engineering Technolgy at Purdue University Calumet in Hammond Indiana. Craig's industrial experience includes 23 years in the aerospace industry focusing on flight and missile simulations and electro optics system analysis. Craig has submitted apporoximately 31 patent applications, received notice of allowance on 24 applications and paid issue fees on seventeen applications resulting in seventeen U. S. Patent Awards so far. He received a masters degree in interdisciplinary engineering from Purdue University Calumet and graduated from Purdue University with a B.S.M.E.

Prof. Gregory P. Neff, Purdue University, Calumet (Tech)

Gregory Neff is professor of mechanical engineering technology at Purdue University Calumet. He is a Registered Professional Engineer, a Certified Manufacturing Engineer, and a Certified Manufacturing Technologist. Greg is active in ASEE where he won the Meryl K. Miller award in 1994 and in SME where he is education & certification chair and webmaster for chapter 112. He is faculty advisor and webmaster for SME student chapter 161 and advisor for Tau Alpha Pi. He is active in ASME, where he has served as national past chair, webmaster, nominations chair, and honors & Awards chair for the Mechanical Engineering Technology Department Head Committee (METDHC) of the American Society of Mechanical Engineers (ASME). He also served the METDHC as national chairman in 2001-2002 and national vice-chair responsible for METDHC technical sessions at the 2001 International Mechanical Engineering Congress and Exposition in New York and national secretary in 1999-2000. Greg has represented ASME as an MET accreditation program evaluator or team chair visiting twelve schools between 1996 and 2006 and served as a member of the ASME Committee on Technology Accreditation from 2002 to 2006. He served on the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC/ABET) as an ASME Commissioner with a term that started in summer 2003 and continued as an alternate member through 2006.

Senior Projects as a Means of Developing Laboratory Experiments and Equipment for Course Labs

Abstract

Due to budgetary constraints at many universities, purchasing commercial trainers and equipment for demonstrating classroom concepts is often a difficult proposition. Since criteria for accrediting engineering[1] and engineering technology[2] programs of the Accreditation Board for Engineering and Technology (ABET) require some sort of a capstone or integrating experience for baccalaureate programs and appropriate industry projects can be difficult to find, designing and building trainers and equipment in-house is an attractive option. Examples of recent senior design projects and project selection criteria that have developed trainers and experimental equipment are discussed.

The paper will provide insights into finding projects that will provide relevant experiential learning experiences for the students involved in addition to gaining university grants or donations from industry while avoiding complications stemming from intellectual property rights.

Project Selection Criteria Based on Constituents' Needs

In-line with the ABET program educational objective criterion 2, the program's constituents' needs are primary. Capstone experiences such as senior design projects as well as undergraduate research projects provide an opportunity for students to demonstrate their ability to attain the objectives within a few years of graduation. Not all of the project selection criteria must be met for every project; but the more criteria met, typically the higher project quality. The project selection criteria based on the program's constituents' needs are:

- Project meets the needs of faculty for program pedagogy, grant fulfillment, faculty research, or employment transition for program graduates.
- Project meets the needs of regional industry or industrial partners for employment transition by developing or integrating technology used by industry or expected to be used in the future.
- Project meets the needs of students for their resume or portfolio with a scope that is doable in the time available, with their skill level, with reasonable cost, and with the expert help available.

Typical non-constituent focused criteria presented by Biney[3] are applicable as well.

Senior Project Courses

In the Engineering Technology Department at Purdue University Calumet, two 3 credit senior project courses, Senior Project Survey and Senior Project, spanning the senior year are required. Typical enrollment has grown to 30 students per semester in each course. The courses serve MET, IET, and Mechatronics ET students in the same classroom. ECET students have similar capstone courses that meet separately with their own instructor. Interdisciplinary projects are encouraged.

The students have varying backgrounds and skill levels with many transferring to campus for their final two years of study. This group includes a sizable number of full-time foreign students from the Middle East. The University is located in a heavily industrialized metropolitan area with a large number of students who are working while attending part-time.

In the first Senior Project Survey course, students are to come up with an idea for a project that interests them and meets (at least) the third project selection criterion (needs of student) above. They must consult with a department faculty member and present the idea in class. If the idea survives comments from the course instructor, department faculty member consulted, and the class presentation audience, a preliminary written proposal with objectives, deliverables, and possible calculations is presented to another department faculty member who must approve the project proposal along with the course instructor and previous faculty member consulted.

Some part-time individual students select projects from work with help and support from their employers who pay all costs and own the results when finished. Other part-time students select a project to design and build something for themselves; possibly to fulfill a hobby interest or to meet a need at home. Roughly half of the senior project students are full-time. These are the students that faculty can most easily recruit to design and build laboratory experiment, trainers, classroom demonstrations, set-ups for families of experiments, or to work on some aspect of the Mini-Baja vehicle, moon buggy, or other competitions. Except for the competitions, faculty advisors generally limit projects to a scope that suits an individual or a pair of students. Students complete the projects by the end of the second course; total one year. How the courses are taught, while interesting and useful, is beyond the scope of this paper.

Senior project students are expected to meet the Standards of Practice for Experiential Education of the National Society for Experiential Education[4] with related outcomes evaluated[i] by the university senate. The instructor for the senior project courses includes the experimental learning questions in the course assessment questions that students answer at the end of the semester. The two courses in the senior project sequence are designated as experiential learning courses required by the University for every curriculum.

Senior Projects Benefiting Labs

Fluid Power – A need identified by the Mechatronics Engineering Technology industrial advisory board was to incorporate programmable logic controllers (PLCs) and pneumatics into course laboratories. Senior project students Jim Bova and Saleh Alkerri over three semesters designed and built a PLC/Pneumatics trainer that will be replicated eight more times by student workers. The components for the trainers have been donated by corporate members of the Packaging Machinery Manufacturers Institute (PMMI): B & R Automation, Bimba Mfg., and Balluff Sensors. Students will control pneumatic cylinders with sensors using IEC 61131-3 ladder-logic diagram and structured text programming

Figure 1- PLC/Pneumatics Trainer Project

[i] To what extent did this course have a real world or applied context?
To what extent did this course provide opportunities to meaningfully reflect on your experience?
To what extent at the beginning of this experience were you provided an orientation appropriate to the content?
To what extent were you provided feedback so you could improve how well you performed?
How well prepared were you to be successful in this course?
To what extent were you provided information on how you will be assessed and evaluated in the course?

languages and B & R Automation Studio software. The components are mounted on 8 by 11.5 inch plastic boards drilled to wing-nut mount on either of two double sided trainer cart vertical mounting surfaces already in the fluid power lab. No additional floor space was required. The component boards can also be used on a table top at remote training sites or at the University's off-campus Mitsubishi PLC training center. The department paid for any equipment not donated.

The first pneumatic trainer built for the fluid power lab was made by Senior Project student George Natt utilizing 110 VAC relays to implement the pneumatics portion of the National Center of Excellence for Advanced Manufacturing Education fluid power curriculum. Pneumatic components were donated by Bimba Mfg. but he paid several hundred dollars for the other components himself which he donated to the department.

Figure 2- 1st Pneumatics Trainer Project

HVAC / Refrigeration – Senior Project student Meschal Alsuwinea transferred into our program after earning an associate degree in HVAC from a college in Saudi Arabia. He chose to do a project to improve the efficiency of the condenser in vapor compression air conditioning equipment operating in very warm conditions (above design temperature of 115º F). Temperatures reach 135 º F for 10-15 days each summer back home. He installed a 3.5 gpm booster pump controlled by a 120º F temperature switch with multiple 0.39 gpm irrigation nozzles spraying on the condenser fins and tubing. He showed increased refrigeration capacity and COP gains for the system using a roof top unit in Saudi Arabia during summer vacation. The lab equipment produced was a window air conditioner using R-22 refrigerant modified by inserting valves on the high and low pressure sides of the system so COP and refrigeration capacity can be calculated. He used an undergraduate research grant to pay for his hardware.

A previous refrigeration trainer was built on a cart from parts by senior project student Johnny Rodrigues. It consists of two R-22 refrigeration systems with different condensers, adjustable speed fans, evaporators, and pressure gauges to compare COP and cooling capacity. The hardware was paid for by the department. Temperatures are taken with a non-contact laser infrared digital thermometer.


Figure 3 - Rodrigues Refrigeration Trainer Project

Thermodynamics -- A senior project under development involves microcomputer control of a single cylinder engine. The bench top laboratory setup is envisioned to provide a tangible context that will assist comprehension of several thermodynamics concepts. Due to the interdisciplinary nature of the project, the project provides the opportunity to create the circumstances that promote assembling faculty members to address interdisciplinary issues as suggested by Green, et al[5]. An additional benefit of merging process control into traditional MET courses enables product development opportunities to be identified which could include the development of a pressure gage operating at high temperatures and/or assessing the feasibility of utilizing alternative fuels. The equipment entices students to experiment by complementing preparation for SAE student competitions.

Heat Transfer -- The heat transfer experiments targeted for development are currently evolving senior projects. They involve the radiative mode of heat transfer. This particular subject matter is a contemporary issue due to their focus on alternative energy sources. The objectives of building the experimental equipment are to provide tangible examples of radiative heat transfer that will assist in the comprehension of the material while establishing a foundation for use in subsequent developments.

One set of experiments developed for heat transfer was predicated on a laser pump cavity[6] invented by R.H. Griest, an employee of Hughes Aircraft during the sixties. The cavity as originally construed consisted of half of an elliptic cylinder with a light source coinciding with one of the pair of line foci and a laser rod located along the other line foci. In order to use the cavity in experiments pertaining to internal flow with constant flux irradiating conditions, the internal flow condition is established around one of the line foci and a light source emitting a significant amount of radiation in the near and/or mid IR wavebands is located along the other line foci. The effectiveness of transferring the energy emitted from the source to the fluid flow is dependent upon several considerations including the ability to conform the reflective surface of the cavity to an elliptic cylinder while maintaining specular reflective conditions. Laser cutting sufficiently thick thin sheets to form support ribs and assembling the ribs enables a thin reflective sheet to be contoured to approximate the desired shape. Due to the tendency of polished stainless steel sheets to exhibit diffuse reflective characteristics, an alternative for constructing the reflector was considered. The technique envisioned for fabricating the reflector involves applying a polyurethane coat to a thin sheet which is subsequently coated with a silver spraying solution all of which are available from Peacock Laboratories. Dip coating of antireflective layers has received attention in the past and accordingly, it may be possible to apply a broad band protective coat on the reflective surface in a cost effective manner consistent with the construction of the elliptic cylinder. The silver spray approach for fabricating the mirror involves a technology and/or related technologies such as chrome plating that can be used in other applications that are typically of interest to the students such as the auto aftermarket. Consequently, the manner of construction of the bench-top equipment should stimulate interest in the experiments in addition to enabling alternative geometries conceived for solar collectors to be realized. In addition, the coating technology could seed investigations into other related areas including electro-less deposition of conductors which would be of interest as subject matter in a materials course which is part of the program.

The investigations to be conducted could span a range of applications. One of the experiments envisioned pertains to experimentally verifying relationships based upon the assumption that the internal fluid flow exists within a tubular form and the transfer of the flux to the fluid occurs via conduction thru a thin wall cylinder and convection thru the boundary layer of the fluid. Replacing the thin walled tubular form with a glass cylinder having an appropriate spectral pass band enables a host of alternatives applications to be considered. Dyes and/or nanoparticles could be added to the fluid and volumetric absorption phenomena investigated. Studies involving alternative source technologies could be performed to identify a technology suitable for creating a monochromatic flux which would facilitate control of volumetric absorption. Laser diode arrays, dye lasers and electrode-less arc lamps operating in the near IR and/or mid IR spectral regions are prime candidates for further consideration. Such a study could form the basis for a collaborative effort and serves to emphasize the value in expanding the perspective of senior design projects initially predicated on the development of experimental equipment using in-house resources.

A second set of experimental equipment has been fabricated as another senior project and involves the use of transparent cylinders and/or transparent plates to fabricate cylindrical forms which are subsequently filled with water creating a cylindrical lens. One cylindrical lens has the shape of a plano-convex cylinder (semicircle with flat back) with a radius of curvature of 3.5 inches on the inside surface and a length of approximately one foot. Acrylic was used to fabricate the initial prototypes enabling the quality of the image to be assessed on a preliminary basis prior to making a commitment to fabricate lenses from more exotic materials. Due to the spectral absorption characteristics of water, cylindrical lenses can absorb a significant amount of IR which facilitates using the lenses in several different applications. The lenses described above could be considered a cold lens, terminology borrowed from the description of a cold mirror. Such lenses could function as condensers in light sources generating large amounts of visible and IR radiation. When used as a solar heat collector, the water to be heated can participate in more than one mode of heat transfer. The utility of such suggestion is presently under investigation. The image quality produced by the plano-convex lens is sharp and rather surprising for such a crude implementation. Techniques for assessing image quality lead to a host of alternative projects. A line scan camera could be employed to measure the line response of the lens produced by imaging a tubular light source having a line filament, such as a low power light bulb typically used in backlighting aquariums available at literally any hardware store. Knife edge scans of the line response could be performed and the equipment necessary to perform the scan

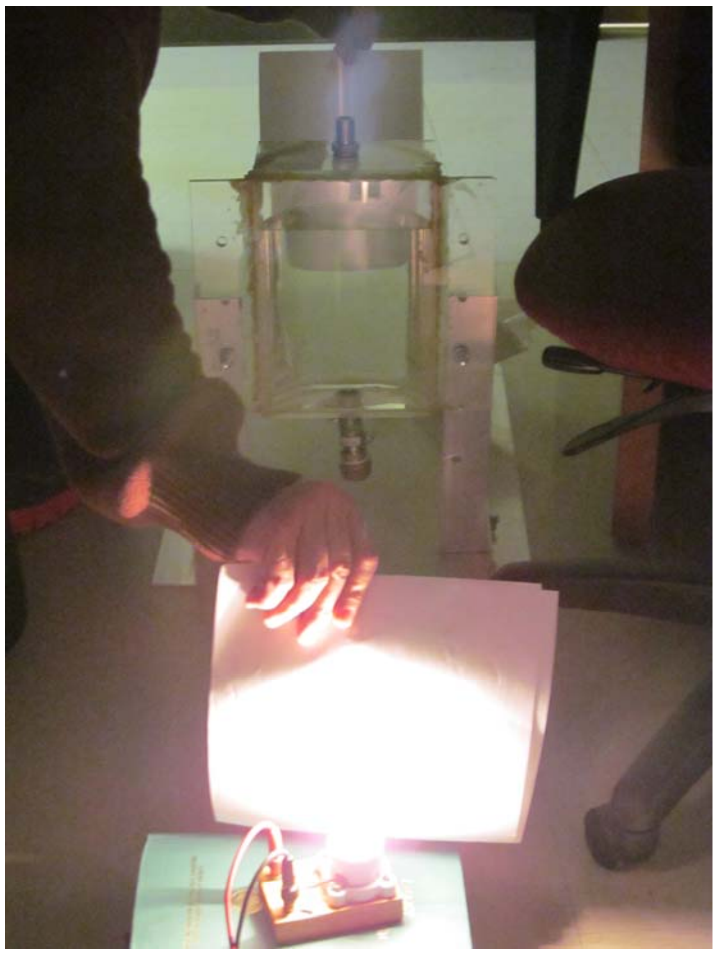

Figure 4 - Plano-Convex Cylindrical Heat Collector Project

could also be considered as development projects. Resolution charts may be imaged and the contrast transfer function measured.

Machine Elements / Vibrations – Another senior project currently underway is the design of a damped oscillator. The oscillator is horizontally oriented and predicated on a modular design concept. The setup will employ standard industrial components. Linear slide bearings were used to constrain the carriage of the oscillator to a one degree of freedom movement which is monitored by a linear encoder having a code strip printed on a polyester film which is read using an Avargo read head. The springs used in the oscillator were off the shelf tension springs purchased from Century Spring. The initial conditions required to evoke a response involve establishing a positional offset from the equilibrium position of the carriage. The carriage is released from the offset by a solenoid latch. The encoder outputs are processed by a quadrature decoder counter circuit also available from Avargo. The output of the decoder counting circuit is sampled and further processed by any number of alternatives enabling the displacement of the carriage to be displayed and utilized to characterize the nature of the damping existing within the linear slide bearings. The frame for the base is constructed from standard framing extrusions used in the packaging industry. The modular design will enable the equipment to be reconfigured as a driven damped oscillator. The driver platform will more than likely be the carriage of the linear slide bearing with the carriage being driven from either a rack and pinion drive and/or a scotch yoke mechanism implemented with a linear way mounted to the carriage. The driven mass is envisioned to be a linear slide bearing having an extended range of travel. Providing the capability to reconfigure as a driven damped oscillator enables the equipment to be used in experiments spanning several courses of the mechatronics program including process control and/or PLC courses. Eventually, load cells could be incorporated to measure spring tension and accelerometers for acceleration to develop a more complete system.

The integration philosophy for the project evolved from the desire to cast the theory of damped vibrations in a context relevant to the industry sectors supporting the program at Purdue Calumet. Utilizing a design that enables a variety of linear motion components to be integrated into the equipment enables the students to develop an appreciation of the differences in performance attainable. These considerations are invariably involved in down-selecting an appropriate design for a particular application. Utilizing industry components to implement linear motion profiles provides a context which facilitates comprehension, is of interest to the students and represents a technique to establish uniformity in the background of students engaging senior design.

Conclusion

Utilizing senior design to develop educational laboratory equipment for use with laboratory experiments predicated on modularity and the integration of industry components enables students with little or no prior hands on experience to be exposed to equipment and/or applications existing in industry. Utilizing the senior design course represents one approach toward establishing uniformity while compensating the for lack of job related experiences in student backgrounds. Developing projects that rely upon vendor literature helps the student to become familiar with components not covered in other courses.

Utilizing standard industry components also enables the faculty to benefit from the senior design project by enabling the faculty to become familiar with the performance capabilities of various industry components and the evolving trends affecting these components. As a result of assessing the performance capabilities of the industry components, the project coordinators can utilize this knowledge to identify product development strategies which can be used to expand the scope of the subsequent senior design projects. In essence, senior design initiates a product development cycle. The development of the senior project should be viewed as a reverse engineering investigation which leads to developing a knowledge base in which to frame subsequent development opportunities. In order to properly recommend subsequent project improvements a systematic review of the patent gazettes or Google Patents is useful. The commitment to such a process raises several issues including the incentives to engage in the development process described, a consideration inherent in the suggestion of how to mediate a collaborative effort described by Green, et al.[7]

Senior project experiences can be selected to require the participants to be involved in the project to a degree sufficient to identify related product development opportunities when the activity is viewed from the proper mind set and accordingly such considerations serve to demonstrate the utility of utilizing senior design projects to create hands-on experiences. To better emulate industry and to insure that the product development strategy drives the selection of senior projects, the assessment of the projects should be on the basis of best effort as is the case with industry related development contracts.

Utilizing the above approach facilitates a progression in the complexity of senior design projects which promotes product development opportunities and intellectual growth while avoiding complications stemming from intellectual property concerns inherent in soliciting projects from industry.

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