Development of an Undergraduate Engineering Research Course

Dr. Arif Sirinterlikci, Robert Morris University

Arif Sirinterlikci is a University Professor of Industrial and Manufacturing Engineering and the Department Head of Engineering at Robert Morris University. He holds BS and MS degrees, both in Mechanical Engineering from Istanbul Technical University in Turkey and his Ph.D. is in Industrial and Systems Engineering from the Ohio State University. He has been actively involved in ASEE and SME organizations and conducted research in Rapid Prototyping and Reverse Engineering, Biomedical Device Design and Manufacturing, Automation and Robotics, and CAE in Manufacturing Processes fields.

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Abstract

This paper presents an effort to develop an undergraduate research course to produce an alternative to a mandatory internship course, Engineering Practice taken by all majors including manufacturing engineering. The new course is labeled as Engineering Research Projects. However, with the growing enrollments and especially in international students, internship placement has become a challenge. The new Engineering Research Projects course will reduce the pressure on Engineering Practice distributing the enrollment in between both courses. It will also accommodate the growing research needs of the department while engaging students in activities that prepare them for graduate study.

The author have been utilizing the internal research projects from the last 10 years as a reference in designing this course. These projects happened under the umbrella of the Engineering Practice course. The new course will be a better match in terms of its requirements. Engineering Practice requires at least 150 hours of engineering work that may include design, analysis, development, maintenance, service, and even technical sales. Each student in the Engineering Practice course deliver a PPT presentation after completing the experience, turn in a final report or a portfolio covering the work done along with a weekly log and journal that describes the activities. Students also complete a student survey to reflect on their experience and are graded by their work supervisors. The new course will also include the minimum hours requirement, weekly journals and logs along with the PPT Presentation. The main difference will be that the students are required to produce scholarly works including conference papers and trade journal articles. Scholarly works of appropriate quality may also be submitted to scientific journals. The completion and submission of these works will be the requirement, not the acceptance.

The course will draw its students from internal and collaborative research projects at the institution along with students conducting research at other local institutions and through NSF REU and other similar programs. The number of students engaging research have been growing rapidly along with graduate study.

Students will be utilizing research databases such as Scopus, Proquest, and Google Scholar, be guided on research methods and scholarly work production. Intellectual Property information and Google Patent will also be an important part of the course if the students develop an original product or process. This course will not replace the interdisciplinary capstone course, Integrated Engineering Design but will be a good complement to it along with Engineering Practice. This paper includes a literature review on including research in undergraduate curriculum, the syllabus including ABET student learning outcomes, and relate to the existing and previous research work done at the institution as case studies.

Introduction

The literature review to investigate existences of undergraduate research courses in engineering yielded examples such as the University of Pittsburgh's International Research Experience for Students Program (IRES) sponsored by NSF[1]. IRES program is a project-based international internship experience in sustainable design where students work in a multidisciplinary research team to solve a complex international sustainability issue. In a similar effort, West Virginia University Microgravity Research Team (MRT) program comprises a two-semester project course sequence for undergraduate students to develop an experimental concept to be examined under microgravity conditions generated by research aircraft if their technical proposal is accepted by NASA's Reduced Gravity Student Flight Opportunities Program (RGSFOP)[2]. Both programs based their activities in project based learning, while the problem statement in the WVU case is open-ended and developed by the students. On the contrary, the Pitt's effort brings cross-cultural design teams in a true international environment. Other efforts such as the one handled by Women in Engineering Program (WEP) at University of Texas - Austin is called Graduates Linked with Undergraduates in Engineering (GLUE)[3]. It is a hands-on and seminar-based undergraduate program linking graduate and undergraduate students based on their majors and interests. The undergraduate students are expected to spend three – five hours on a research project conducted by their graduate counterparts and attend a weekly seminar on research opportunities, graduate school and career development earning undergraduate engineering credit. Another effort, by Tufts University, aims at engaging first-year engineering students (who chose the Window on Research and Scholarship option) in reuse of waste materials by developing and implementing process research under the advisement of a faculty member, leading to a poster presentation[4].

This paper presents an effort to develop an undergraduate research course to produce an alternative to a mandatory internship course, Engineering Practice taken by all majors including manufacturing engineering at this institution. The new course is labeled as Engineering Research Projects. However, with the growing enrollments and especially in international students, internship placement has become a challenge. The new Engineering Research Projects course will reduce the pressure on Engineering Practice distributing the enrollment in between both courses. It will also accommodate the growing research needs of the department while engaging students in activities that prepare them for graduate study, goals similar to many teaching institutions.

Engineering Practice and Undergraduate Research Projects

The author have been utilizing the internal research projects from the last 10 years as a reference in designing this course. These projects happened under the umbrella of the Engineering Practice course. The new course will be a better match in terms of its requirements. Engineering Practice requires at least 150 hours of engineering work that may include design, analysis, development, maintenance, service, and even technical sales. Each student in the Engineering Practice course deliver a Power Point presentation after completing the experience, turn in a final report or a portfolio covering the work done at the workplace, a weekly log and journal that describes the activities. Students also complete a student survey to reflect on their experience and are graded by their work supervisors. Final grade is based on student work and the supervisor feedback including a feedback form and overall evaluation. The new undergraduate research course will

also include the minimum 150 hours requirement, weekly journals and logs along with the PPT Presentation. The main difference will be that the students are required to produce scholarly works including conference papers and trade journal articles. Scholarly works of appropriate quality may also be submitted to scientific journals. The completion and submission of these works will be the requirement, not the acceptance.

Engineering Research Projects will draw its students from internal and collaborative research projects at the institution along with students conducting research at other local institutions and through NSF REU and other similar programs. The number of students engaging these type of activities have been growing rapidly along with continuation to graduate study.

ENGR 4940 Undergraduate Engineering Research Projects

The course syllabus for this undergraduate course is embedded into the body of this paper. The course description implies that this course will be "of a well-defined and academically supervised basic or applied engineering research project experience leading to a scholarly work. Research terminology, literature review process, formulating and justification of research problems, research ethics, quantitative, qualitative and mixed research methods, analysis and interpretation of their data, and citation styles will also be included along with writing examples for conference and journal publications. 3 Credits"[5].

The goal is to immerse students into research settings that will allow them to apply theoretical and experimental concepts learned in the classroom to solve basic and real world engineering problems[5]. Following ABET (a through k) student outcomes may be targeted in this course if the course project is based on individual student work and there is a match between the student work and the specific outcome below:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

If the project is based on a team effort, the following ABET student outcome will be also included:
(d) an ability to function on multidisciplinary teams

This course is an undergraduate research experience course, not a typical course taught in a classroom setting. Accordingly, the syllabus presents the information provided to the students as they undertake this required research experience[5]. Following subjects will be covered by supplemental handouts including templates and sample work[6] and will be reinforced by doing:

- Safety, health, and environmental requirements (dependent of the project nature)
- Research terminology
- Literature review process
- Formulating and justification of research problems
- Research ethics
- Quantitative, qualitative and mixed research methods, analysis and interpretation of their data
- Citation styles
- Research writing examples for conference and journal publications.

Grading of the course will be based on the following components and criteria:

- Journal/Log- 25%,
- Final Report as a scholarly work- 35%,
- Seminar Presentation-10%,
- Supervisor Evaluation - 25%,
- Other Pertinent Requirements-5% (including Progress Report Contact with the Research Supervisor and Student Evaluation Form)

Deliverables

During the course of the research experience, the student must develop and maintain a weekly journal, to serve as a tool for his/her recording learning experiences. The journal should be a log of the student's activities and a collection of thoughts and insights gained from these activities. It is expected that the journal entries will attempt to relate the work activities of each week to the coursework completed thus far in the student's academic curriculum. The journal may contain any dilemmas or problems and related solutions or courses of action taken.

A final report is also mandatory. This is above and beyond the weekly journal and Student Evaluation form. The format and topic(s) of the final report is left up to the student with the approval of the research supervisor. The intent of the report is to prepare a scholarly work document to be submitted (acceptance is not a requirement) in the form of a conference, scientific and trade journal paper, technical meeting or conference presentation.

A seminar will be scheduled at the end of the term. At this seminar, students provide a brief presentation about their research experience and answer related questions from the attending faculty and other students. The presentations generally confirm that the students are in fact involved in educationally-appropriate engineering research projects. During the seminar, the research supervisor can clarify, if needed, the course deliverables and administrative evaluative procedures that lead to the individual grades. The seminar also provides the students with an opportunity both to reflect on the value of the course work that had prepared them for the

experiences and to propose any modifications to the courses to improve their preparation.

The student evaluation form is also to be completed by the student and turned in at the end of the term. (The return of this form will be necessary before a grade can be issued.)

Conclusions and Future Work

This paper sketches a newly developed undergraduate engineering research course to present an alternative to the mandatory internship course at this undergraduate teaching institution with growing research needs. The university has just became a Carnegie classified institution due to growth of its doctoral programs, and a large number of papers, presentations, and posters were recorded in 2015- 2016 AY by the Engineering Department. The author's research work in Reverse Engineering, 3D Printing/Additive Manufacturing, and Modular Robotics has been made possible by contributions from students who were eager in learning more by doing, problem solving, and skills development, who also took the previous Engineering Practice course. The recent student-faculty research collaborative work in SHE (Safety, Health, and Environmental) Subjects in 3D Printing led to multiple journal papers, including a recognition from Emerald Literati Network by a Highly Commended Paper Award[7]. Original work in 3D printing material development have also been carried out by students were enrolled in Engineering Practice to be shifted to this new course.

With the new research course, each student or student team will be matched to a faculty member based on their interests. The capstone course at this department is usually an interdisciplinary one. The new research course projects may also include a good number of interdisciplinary ones.

Within the last few years, the undergraduate students applied for and earned multiple provisional patents, some of which were results of competition wins including the SAP's Utility of Tomorrow Contest featured in Forbes Magazine[8]. Future work will include attempts on obtaining grant funding, and start-up and enterprise efforts through another course being prepared.

While this course helps development of engineering students for possible future graduate study and channel them into employment in academia, it may keep them away from the industrial opportunities. However, it may also help student gain placement at R & D entities of different industrial sectors. Results of these will be seen in the near future.

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