Research and Lifelong Learning Skills in Engineering Education

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Abstract

Research is an integral part of undergraduate education and research experience is becoming essential in engineering where technology is giving rise to unprecedented speed and efficiency in the use of complex scientific methods in engineering applications. Similarly, skills in lifelong learning are becoming imperative for engineers to cope with the ever-changing demands in the workplace during their professional career. The elements of undergraduate research and lifelong learning skills are presented in this paper and two courses are suggested as mechanisms to foster this education in the engineering curriculum.

Introduction

Numerous studies conducted on the undergraduate engineering program emphasized the importance of the basic elements of mathematics, natural sciences, engineering sciences, and fundamental concepts of analysis and design [1-4]. These studies also called for emphasis on synthesis and design, depth and strength in the technical subjects, greater emphasis on deeper inquiry and open-ended problem solving, communication skills and preparation for continuing professional development and career long learning. In addition, the studies emphasized the importance of non-technical education, management skills, interdisciplinary and international exposure [5].

However, engineering faculty and students are faced with an already tight curriculum, and satisfying such a broad set of demands within the traditional program seems extremely difficult. A number of topics such as management skills and interdisciplinary and international exposure are necessarily ignored in many engineering curricula in the hope that students will gain such knowledge and skills elsewhere. The pressure of time also forces a scant coverage of important areas such as research and scholarly investigation of open ended problems, communication skills and preparation for professional development and lifelong learning.

While some engineering schools are revamping their whole programs to include these topics [5], other programs are using simple mechanisms such as required or elective courses to integrate these topics in the traditional curriculum. Two course that are used to introduce undergraduate research and lifelong learning skills to engineering students are discussed in this paper. The first is a required one-credit engineering seminar course, and the second is an elective independent study course.

Elements of Research and Lifelong Learning Skills

Research experience is very valuable to undergraduate engineering students. It provides them with an opportunity to engage in a long-term open-ended project that involves deep inquiry in their field. The experience provides an intellectual challenge that often fosters a creative spirit, a capacity for critical judgment and enthusiasm for learning. In addition, the research experience improves the students' problem-solving and communications skills, enhances their self-confidence and gives them a sense of accomplishment beyond classroom learning. Furthermore, it gives them a sense of wonder and discovery, a yearning for more discoveries and learning, and the skill of self-motivating and self-teaching. This in turn puts students on a path of lifelong learning and prepares them for continuous professional development throughout their career.

Research is defined as the scientific or scholarly inquiry or investigation, and the proper communication of the findings; or as the use of resources to expand the knowledge base, or to solve a particular problem and develop a new product, methodology, and to uncover previously unknown facts or principles [6]. The major role of research in undergraduate education is to provide students with an understanding of the fundamental principles, and the use of these principles in a scientific process to expand the state of knowledge in a specific area in the discipline. This scientific process consists of four major steps, namely, observation, hypothesis, experimentation, and induction.

Scientific observation is crucial both to define a problem and to collect data or recognize effects that occur during research. An important step in making an observation is the immediate recording of the observation in a notebook. The hypothesis is a formal expression of a preconceived relationship that the student uses to guide his or her research. The experimentation phase is the systematic controlled testing of the hypothesis which can be performed in the laboratory, using computer simulation, field experiment, field study, or survey research. In conducting the experiment, it is important to record every detail. Here again, keeping good records of work completed, decisions made, errors and corrections during experimentation is a key activity to successful research. The last step, induction, is the process of interpreting the data obtained from the experimentation to develop some general conclusions that will support, invalidate, or redesign the hypothesis [6]. These four steps are vital to any research project and should be performed with utmost care and rigor.

In addition to being proficient in the research process, students should be aware of the positive attitude for success in research. This includes setting realistic goals to motivate the student, having a good mental preparation and an I-can-do-it attitude, learning to enjoy the research activity and to be persistent in overcoming setbacks, and being curious to investigate a problem and question the results. These traits are not only essential for research but they also formulate the characteristics of the inquisitive lifelong learner who is ready to take learning beyond personal knowledge and advance the state of the art in the discipline. The opportunity to learn these skills in undergraduate engineering programs is hindered by many factors. One major factor is the lack of time and place in the curriculum for students to learn and practice the skills of research and lifelong learning. In the following sections, two courses in which these skills can be taught, developed and nurtured are described.

The Engineering Seminar Course

The seminar course is one of the few courses in the engineering curriculum that can be fully dedicated to learning the tools of and conducting research, and to developing lifelong learning skills at the undergraduate level. The course is offered in many engineering programs with different number of credits and various degrees of emphasis on research and problem solving skills. In the composite materials engineering program at Winona State University (WSU), the engineering seminar is a one-credit required course in the upper level junior or senior years. The objective of the course is to develop research and lifelong learning skills. The course is designed to enable students to engage in independent research on a topic pertinent to engineering.

Students are given the syllabus of the course at least one semester before the course begins, and are introduced to the basic elements of research which include planning, strategy, and development of ideas. Many students prepare and work on their topics during the summer. In the first three weeks of the course, students learn the research methodology, how to conduct literature search, define a problem and perform an investigation, collect and analyze data, draw conclusions, and present their findings. During the course, students discuss their topics with the course coordinator who mentors them on their research projects. The course takes place over two semesters and each student is required to submit an abstract, write a two-page paper, and give a 40-minute presentation to students, staff, and faculty on their research topic and findings. An example of an abstract is shown in Figure 1. The paper and the presentation are evaluated by all the faculty in the department and the evaluations are given both orally, after each presentation, and in writing. Students also participate in peer evaluation using prepared evaluation forms.

In addition to developing their research skills, students gain experience in oral communications and professional presentations in which they express ideas, defend their thesis, and advance solutions and conclusions to an audience. During the course, students develop skills in lifelong learning and organizing ideas, thoughts, and theses for publications and presentations. Students also learn to share ideas and information in professional settings and to give feedback to and receive feedback from peers in the seminar. They learn from colleagues, professionals, and their own work how to continuously improve their research and communications skills.

The course promotes students' abilities to make use of the technologies in research, experimentation, data collection, analysis and presentation. Students learn the conventions of evidence, format, usage, and documentation in their field; understand the features and types of speaking in their disciplines; and adapt their speaking to field-specific audiences. They emerge from the course with a sense of confidence and the tools to handle and learn from future projects.

The Independent Study Course

This is an elective course designed for the undergraduate student who wishes to engage in research. The subject of research and the number of credits, ranging from one to three, are arranged with the instructor. The major objective of the course is to allow the undergraduate student to engage in research related to composite materials engineering. Students acquire the knowledge and skills to identify and define a research topic, perform the necessary literature search, plan and design their research activity, collect and analyze data, and conclude their study. Furthermore, students are expected to enhance their technical writing, communication, and presentation skills.

Topics covered in the course include: identification of research topic; research proposal writing; literature search; design of engineering models; design of experiments; data acquisition; data analysis; technical report writing; and effective communications. The instructional plan consists of individual one-to-one instruction and advising to be arranged between the faculty and student. The instruction consists of fifty minutes of discussion per week per credit. Students are expected to spend a minimum of three hours per credit on literature review, laboratory work, data analysis, and progress reports. Students are required to submit a final report to the faculty advisor and give an oral presentation and defense to a faculty committee.

The course provides undergraduate students with a hands-on experience in research. Unlike the summer research experience for undergraduates in various research universities, the independent study course is more comprehensive as it usually extends for more than one semester, it offers more one-to-one student-faculty interaction, and provides a sense of ownership and commitment to students seeking academic credit at the end of the course. The course also offers the student and faculty an opportunity to publish the findings in a journal paper, conference proceedings, or poster sessions at engineering symposia.

Conclusions

Research and lifelong learning skills are important components in engineering education. Conventional courses such as the engineering seminar and the independent study course can enable undergraduate students to learn the research process and the steps of the scientific method of research through hands-on experience in the engineering curriculum. This knowledge and experience complement students' classroom learning and prepares them for higher and lifelong education.

References

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"Single-Wall Carbon Nanotube as Thermal Conductive Filler in Polymer Composites"

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Abstract

Polymer composites are preferred over metals in thermal conductive applications because they can be thermally conducting and electrically insulating. They can also be both thermally and electrically conducting. Moreover, they exhibit better chemical stability (e.g. resistant to corrosion) and desirable physical properties (e.g. low density). The Hashin-Shtrikman equation is used to predict the upper and lower thermal conductivity of single-wall carbon nanotube (SWNT) filled PolyVinylideneFluoride (PVDF) Composite, as a function of thermal conductivity and volume fraction. The high thermal conductivity constant and high aspect ratio found in single wall carbon nanotube makes it a good candidate as thermal conductive filler in polymer composites. In this study, the thermal conductivity of unpurified (35 vol%) SWNT filled PVDF was measured at various volume fractions. The results show that 40 wt% of SWNT is needed to increase the thermal conductivity of the polymer by 100%. The curve of SWNT volume fraction versus the thermal conductivity of the composite falls below the lower boundary of the Hashin-Strikman model. The high percent loading could be due to: unconfirmed SWNT distribution, purity of SWNT and that the Hashin-Shtrikamn model does not take into account the presence of dislocations that might have reduced the thermal conductivity of SWNT as well as the filler's aspect ratio and particle size (nano-size).

Figure 1. Typical Abstract of a Research Paper in the Senior Seminar Course