The "T-Shaped" Learning Experience at Worcester Polytechnic Institute

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Abstract

As the 21st century progresses, the engineering profession faces many challenges that have created a demand for engineers with 'T-shaped' skills. These "T-shaped" skills not only require depth of knowledge in the field but also a breadth of skills such as proper communication, leadership, and creativity. This paper presents the experiences of Worcester Polytechnic Institute (WPI) in introducing 'T-shaped' skills to students through curriculum and internship opportunities. The methods by which the Civil Engineering department at WPI weaves 'T-shaped' skills into an NSF-funded Research Experience for Undergraduate Research (REU) program, high school internships, and senior design projects are discussed. Assessment of these efforts showed improved depth (learning concepts/knowledge) and breadth (application of knowledge, communicating the knowledge, and presentation of knowledge) of the students in the programs.

Keywords

'T-shaped' skills, NSF-funded REU program, high school internships, senior design projects

Introduction

The development of engineering education has evolved over time[1]. In the nineteenth century and in the first half of the twentieth century, engineering education put major emphasis on "hands-on" experiences. As the remaining second half of the twentieth emerged, the paradigm shifted towards including more science and mathematics in the curriculum. However, entering into the twenty-first century, further changes have become necessary. Curriculums across higher education schools are adjusting to the need for students to attain knowledge beyond the traditional science and mathematics skills. Rather they are clearly defining the need for engineering students obtain 'soft skills' such as communication, leadership, and creativity skills[2]. These changes have led to the twenty-first century's need for the 'T-shaped' professionals.

The term 'T-shaped' refers to a professional who obtains both depth (the vertical line of the T) and breadth (the horizontal line of the T). Depth is the knowledge one has in the specific area of study and breath refers to 'soft skills' such as collaboration and communication. Professionals with 'T-shaped' skills are more likely to be better problem solvers and excel within their profession[3-4]. This emerging necessity has led to the development of incorporating 'T-shaped' skills within the engineering education curriculum[5].

Worcester Polytechnic Institute (WPI) was founded in 1865 with the mission of educating "talented men and women in engineering, science, management, and humanities in preparation

for careers of professional practice, civic contribution, and leadership, facilitated by active lifelong learning"[6]. In doing so, WPI has designed the school's curriculum to achieve these goals by creating the *WPI Plan*. The *WPI Plan* takes on project-based program in addition to the required coursework. There are two major projects necessary for all students. The *Major Qualifying Project* (MQP) allows students to investigate problems that they may face within their profession. This is typically conducted during the student's senior year at WPI. It allows the students to delve deeper into a certain practical issue within their major. This may involve collaborating with a company, a redesign of a structure, or research. The *Interactive Qualifying Project* (IQP) is a project that deals with societal issues and technology. Typically students complete the IQP during their junior year at WPI where they can travel abroad and work with on an issue that the country/region may be facing. Additionally, students are required to complete a Humanities and Arts Practicum/Seminar generally during their sophomore year. Since these projects are traditionally group projects, this encourages collaboration, leadership, communication skills, etc. The projects which WPI has integrated within its curriculum are a technique and method of educating students to be exposed 'T-shaped' skills and eventually become 'T-shaped' professional.

The Civil Engineering department at WPI not only uses these required projects to encourage 'T-shaped' skills amongst their students, but also incorporates other programs to promote such skills to various students including non-WPI students. The department has a high school internship program where the high school students shadow and assist a graduate student with research. Also, the department hosts an NSF-funded Research Experience for Undergraduates (REU) program where local undergraduate students work on a research project. These programs all have a commonality where the 'T-shaped' skills are integrated within the student's experience.

This paper discusses methods of which the Civil Engineering department at WPI incorporates techniques into the programs they are involved in to expose the students to 'T-shaped' skills. Since the programs generally take place in a research lab environment, this paper will refer to the experiences regarding to research. The paper is grouped into three sections. The first section discusses techniques for teaching depth of knowledge, the second section describes the methods of incorporating breadth, and lastly the outcomes of these experiences. Assessment of these efforts showed improved depth (learning concepts/knowledge) and breadth (application of knowledge, communicating the knowledge, and presentation of knowledge) of the students in the programs.

Depth

When the students begin a project/program involving research, it is vital to clearly define and outline the research that is to be conducted[7]. This will ensure that the students understand what is being investigated and why. In order to accomplish this task for the REU students in the Civil Engineering department at WPI, the two major steps are carried out. First, the students undergo a 'crash course' on the research that they will be involved in and conduct a background/literature review. The following describes both steps.

'Crash course'

Prior to the students working in the lab/on a project, a 'crash course' is carried out. This involves the mentors (the professor or the graduate students who work with the students) to describe the scope of the project that the student is to be involved in. Many times, students are 'thrown' into a project and asked to do a specific task. However, many times the student does not fully understand what the project is actually about and thus a deep understanding of the research is not achieved. This 'crash course' includes a background on the topic as well as demonstrations. It is important to note that this course is not a traditional course where the subject is taught and then a test is given to assess the student. Rather, a different learning style is carried out where the course is discussion based. By talking to the students, the mentor can gauge the knowledge the student presently obtains on the subject matter and therefore can understand what needs to be explained. For example, when introducing the topic of research of corrosion in concrete structures to the high school interns and REU students, the purpose of researching corrosion of the reinforcing steel within concrete was at first unclear to the students. They did not know that concrete structures had reinforcing steel embedded within. However, by both explaining the reasons and showing the students actual reinforcing steel and concrete samples, they were able to fully grasp the motivation for such research. By including a 'crash course' to the program, the mentor can get a good understanding of the student's knowledge as well as determine the student's learning style. Therefore this 'crash course' can help improve the quality of the research for both the student and mentor.

Background/literature review

Once an oral explanation of the project is carried out through the 'crash course', the students then begin a literature review. For students to conduct research on a topic, he/she must first understand the problem that is trying to be solved and be aware of the studies that other researchers have previously conducted. This also gives the students exposure to the practical side of research and what a common researcher would have to do in the profession.

The mentor provides articles to the students to read before the start of a project. Since the information that is being studied is usually new to the students, the mentor will read and discuss the paper together to ensure the student understands what is written. Before conducting any experiment in the lab, the students are asked to read and understand the methods and standards that are provided by the American Society of Testing and Materials (ASTM). These standards provide required information related to the materials that should be used for any experiment, the step by step description of conducting the test, and the acceptable errors of the test. Reading these standards give the required information about the materials that students need and the procedures that they should follow to conduct the tests. Therefore, it makes it clearer for them to compare and contrast their results with other studies.

Breadth

In the engineering and research profession, breadth is critical. Presenting research ideas and results is important since that is how others can know about what is being investigated. This may be done by an oral presentation, a written article, communicating with possible collaborators, etc. Therefore, there are several approaches including weekly meetings, lab work, and preparing reports and presentations which have been included to incorporate these breadth qualities into the programs.

Weekly meetings

Once a week the students meet with the entire research group. In the meetings, results are presented and discussed. This allows all members of the group to collaborate on ideas, provide input, and explain future studies. One major benefit to the weekly meetings is that it allows for the students to bring up any questions or concerns and ensures that everyone from the group is on the same page.

Hands-on approach - Lab work

The students took on a hands-on approach to the lab work. They prepared samples, ran equipment, and analyzed the results. Their mentors initially worked with the students and taught them the techniques and methods necessary. By having the students produce independent research and results, the students were able to have more of a realistic understanding about research and also gave them a better sense about aspects such as the dimensions, weights, and the general numbers that they are working with.

Moreover, complementary to conducting laboratory experiments, the students recorded and analyzed data. They were taught how to record data and the experimental results in a scientific method. For example, students were provided a lab-notebook and were asked to record all the lab tests and results in detail. This included documenting the date for each experiment, using pen to record data, putting a descriptive notes, etc. This is important since the programs not only strive to provide the technical skills to young engineers and researchers, but also teach them about academic and engineering honesty.

Preparing reports or presentations

Presenting research can be just as important as carrying out the research itself. This can be completed through oral or written explanations. In doing so, students are asked to assist in preparing a report such as a journal article on their project. The students can become the co-author of the paper which encourages them to take responsibility and ownership of their project. It also teaches them technical writing skills as well as helps them to further understand their work since they have to explain it in writing.

Additionally, at the end of their program the students are asked to present an oral poster presentation. For the REU program, a poster session was held where each student presented their research (Fig. 1). Guests were able to view the posters as well as ask the students questions and discuss their research. A similar type of presentation is held annually for the senior projects (MQP) and their presentations are judged by a panel of industry related professionals. A poster presentation further encourages and gives the students practice to communicate their findings to those who may not know much about their research.

Figure 1: REU student present her research on the project presentation day

Example Outcome

Results from utilizing both the depth and breadth techniques ('T-shaped' skills) that the Civil Engineering department uses has shown to be effective. An example can be drawn from an REU student. This particular student was a sophomore from another university. The student's knowledge on the assigned research topic was very general prior to the start of the program. As the student began the WPI program following the depth and breadth strategies, the student rose to the task of taking on a large part of the research. The student started contributing ideas and had scientific evidence to back-up the proposed ideas. Also, the student would conduct experiments and analyze the results. The student used the information collected and has become a co-author to an article. Moreover, even after the REU program was completed, the student submitted an abstract on the research conduct at the WPI REU site to a conference. The abstract was accepted and the student attended the conference to present the research. Similar successful outcomes have been seen with other students who have also completed the breadth and depth process which the Civil Engineering department uses at WPI.

Conclusions

Engineering education changes over time. As for the twenty-first century, the shift has been towards exposing students to a 'T-shaped' structure. Schools of higher education, such as WPI, have incorporated these 'T-shaped' skills within their program. By encouraging both depth and breadth within a curriculum or program can increase the student's possibility of success within the student's future professional career.

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