PREPARING STUDENTS FOR SUCCESS THROUGH IMPLEMENTATION OF A UNIFIED CURRICULUM DESIGN SPINE

Roger Carrick and Alex Czekanski.
Department of Mechanical Engineering, York University
roger.carrick@lassonde.yorku.ca, alex.czekanski@lassonde.yorku.ca

Abstract - Preparing students for the technical aspects of engineering practice has not been difficult, as the teaching strategies and learning outcomes are well developed. The teaching of so-called “soft-skills” such as communication, teamwork, project management, and design, however, are more difficult and varied in their strategies.

In this paper, we examine the design curriculum as implemented by York University’s Department of Mechanical Engineering and discuss the advantages of promoting soft-skills development through team design projects, and outline continuous improvement processes we undergo to ensure we are giving students the training they need to practice engineering. Finally, we discuss our planned studies that will track the effectiveness of the design spine as students enter the workforce.

Keywords: Curriculum Design, Course Design, Design Projects, Soft-Skills

1. INTRODUCTION

Design may not be at the top of the list attributes that engineers cite as most important in their professional careers [1], but this may be due to the variety of professional positions that engineers occupy, some of which may not directly contain elements of design. Design courses however, particularly project based design courses, are excellent methods of teaching and developing the top ranked attributes: teamwork, communication and problem solving [2]. Ultimately, the goal of these projects is to move students to higher levels of understanding or skill within these attributes, and do so in a manner that reflects professional practice as closely as possible.

While Capstone projects have been found to be effective, students may not have had a chance to develop the technical and interpersonal skills required to effectively complete a large-scale, open-ended, multi-disciplinary design project if their only other exposure to design occurred in their first or second year introduction to design course. For undergraduate engineering students, earlier exposure to and training in the design engineering process holds much value for an enriched experience and an in-depth understanding of engineering design.

In a survey of design courses at the 27 CEAB accredited mechanical engineering programs across Canada, it was found that all universities included a capstone project, although only a few did not require anything past a paper design. 23 out of 27 had first year courses mentioning design or design process, while only 7 out of 27 had courses directly related to design, or design projects in each of the 4 undergraduate years. Keywords in the course outline search were design project, design process, prototype and build. This shows that while universities do consider design important through the implementation of cornerstone and capstone courses, not all have implemented design practice throughout their curriculums.

To prepare students for their Capstone design course, and develop their soft-skills, York University’s Lassonde School of Engineering’s Mechanical Engineering Department has implemented a Design Spine program that introduces design project courses during each year of the undergraduate curriculum. These courses are specially designed to introduce students to gradually increasing levels of problem and solution abstraction. Additionally, they provide an opportunity to apply the theory and technical skills from their other courses to reinforce the theory through practice and application.

In this paper, we will examine the advantages of having term-long design project courses throughout the undergraduate curriculum, as well as the benefits of applying a unified design process to any smaller scale projects outside of the core design spine. Additionally, we will highlight specific strategies we use to promote skills such as teamwork, communication, and professionalism. We will also highlight proposed methodologies for the evaluation of the effectiveness of curriculum as students graduate and enter the workplace.

2. BACKGROUND

2.1 Important Skills

The Canadian Engineering Accreditation Board (CEAB) outlines 12 attributes which graduates of engineering programs must possess at appropriate levels of achievement.
Table 1: CEAB Graduate Attributes

<table>
<thead>
<tr>
<th>CEAB Graduate Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Knowledge Base</td>
</tr>
<tr>
<td>2 Problem Analysis</td>
</tr>
<tr>
<td>3 Problem Investigation</td>
</tr>
<tr>
<td>4 Engineering Design</td>
</tr>
<tr>
<td>5 Use of Engineering Tools</td>
</tr>
<tr>
<td>6 Individual and Teamwork</td>
</tr>
<tr>
<td>7 Communication Skills</td>
</tr>
<tr>
<td>8 Professionalism</td>
</tr>
<tr>
<td>9 Impact on Society and the Environment</td>
</tr>
<tr>
<td>10 Ethics and Equity</td>
</tr>
<tr>
<td>11 Economics and Project Management</td>
</tr>
<tr>
<td>12 Life-long Learning</td>
</tr>
</tbody>
</table>

While these are the required graduate attributes, universities are given a certain amount of freedom in the relative emphasis that they place on specific attributes. Determining which attributes are most important has been an important subject of research [1,3-11]. As the ultimate goal for an undergraduate program should be to prepare students to practice engineering, surveys focus on practicing engineers or employers. Trying to get a definitive answer can be difficult because of the extremely varied nature of engineering practice. Different academic disciplines will rank attributes differently, for example, industrial engineers and manufacturing engineers have been shown to rank graduate attributes differently. Similarly, the work environments will influence how important some attributes are ranked. An operations engineer at a manufacturing plant, a designer at a startup and a consultant may all rank teamwork differently [11]. Finally, achieving consensus in aggregation of surveys can be difficult as the phrasing used can also influence the results. Despite these challenges, the most important aspects cited are Teamwork, Communication and Problem Analysis [1]. Despite being the most important skills cited, they are often afterthoughts in most courses.

2.2 Soft Skills Development

Generally, when we talk about skills or knowledge, we wish to evaluate how well, or to which level the students have attained or understood the outcome. Taxonomies of learning are applied to codify student understanding, which can be used to evaluate final outcomes, and for continuous improvement of courses. Common taxonomies are Bloom’s, as updated by Anderson & Krathwohl [12], or the Structure of Observed Learning Outcome (SOLO) taxonomy by Biggs and Collis [13]. Taking the SOLO taxonomy as a model, learning is a hierarchy, where each level becomes a foundation on which further learning is built.

![Figure 1: Representation of the SOLO Taxonomy hierarchy](image)

In this model, each level must be completed before the student can proceed to the next learning level. We can apply this model to soft-skills such as teamwork and communication in a similar fashion to technical knowledge. In order to help students achieve high levels of learning, we must give them opportunities to train these skills, as well as give them tools and practices that they can train these skills.

Design projects, particularly large scale design and build projects are important vehicles for promoting teamwork and communication [2]. Teamwork is the most desired outcome from working on team projects, and most closely emulates how engineers operate in professional practice. Particular aspects of teamwork that are important to emphasize in team projects are interdependence, trust and shared mental models, while at the same time avoiding social loafing and conflict [2].

2.3 Design Skills Development

Design can be a nebulous topic to identify, and before examining design skills, it is important to define the design process. Dym and Little define it as “A systematic intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints” [14]. More simply, it is the process by which engineers apply theory and skills to solve practical problems. There are numerous variations of the engineering design process, each of which may be specifically suited to a specific task, discipline or corporate structure. Whatever the variation, they should all be an iterative process involving Problem Analysis, Conceptualization, Design, Testing and Analysis. In the experience of the authors, problem analysis is by far the step that students have the most trouble with, particularly when dealing with poorly-defined, open-ended problems.
Students have difficulty determining problem scope and setting realistic constraints and performance goals.

3. DISCUSSION

3.1 Design Spine

At York University’s Lassonde School of Engineering, the Department of Mechanical engineering has applied a design spine curriculum. This design spine promotes a steady building of the students design abilities through dedicated design project courses every year of the curriculum. Additionally, a large emphasis is placed on promoting soft skills such as teamwork and communication.

Teams were given a chance to develop “team contracts” stipulating the teams’ teamwork objectives and behavior requirements. Teams were given collaboration and communication tools, and periodically, they evaluated themselves and their peers through an online peer evaluation tool, TEAMMATES. This allowed students to give each other feedback, and communicate any issues discretely to instructors.

Additionally, during second year, there are several other courses that include smaller scale design projects. Aspects of team formation and collaboration, design process and requirements, as well as deliverables are shared between these projects to ensure consistency of message, as well as reiteration and further development of the skills.

The third-year design project course is similar to the second-year design course, however the problem is underdefined, with only a few constraints placed upon the students. Students must focus more on problem definition aspects such as determining use cases, identifying stakeholders, and developing performance benchmarks. This project is selected to ensure that it introduces aspects of both fluid dynamics and heat transfer. Application of theory is an important aspect of the design spine as it adds context to the theory based courses and builds confidence in their ability to apply their training to real world applications.

The final Capstone project is handled in a similar manner to other universities, following a two-term structure, with the majority of the early stages of the design process occurring in the first term, while much of the building and testing takes place in the second term. Beyond the extension of the scale of the project, and their open-ended nature, is the interaction of students with an external stakeholder in the project. These external stakeholders, be they industrial partners, or researchers, ensure that project requirements and objectives do not drift over time as students run into roadblocks as can be seen in projects defined by students. Real stakeholders are essential in ensuring that students are exposed to an environment that closely simulates actual practice instead of an academic exercise.
3.2 Design Curriculum Evaluation and Continual Improvement

In addition to traditional course evaluations, we seek feedback from students specifically regarding design and soft-skills development. These evaluations take the form of student surveys, taken at regular intervals as well as focus group and individual interviews with students. These studies seek to determine students’ motivations, as well as their feedback regarding design in general. The results of these studies are reported elsewhere, and provide valuable feedback for the continual improvement of design courses and soft-skill training tools.

As our first cohort of students prepare to graduate, we plan on tracking their progress in the workforce. The planned survey to recent graduates will consist of the following components. First, graduates will be asked to evaluate the importance of each of the twelve CEAB graduate attributes in their professional experience. This information will be used to test the null hypothesis that there is no difference in the importance of the CEAB graduate attributes. Second, short answer questions will be collected on the nature of design in their career, what tools they use in design, as well as any aspects of design or related training that they believe was missing from their undergraduate curriculum. These responses will be collected, categorized, and brought forward to an action committee to ensure continuous improvement of the curriculum to meet the needs of today’s graduates.

4. CONCLUSIONS

Preparing students to practice engineering should be the goal of any engineering curriculum. Design is the process by which engineers practice. Ensuring a robust design curriculum that prepares students to: apply the skills and knowledge they acquire, meet the challenges of real world problems, meet the needs of society, work effectively in diverse, multi-disciplinary teams and communicate effectively.

In this paper, we present the design spine approach as enacted by York University’s Department of Mechanical Engineering. The design spine allows a gradual building of students’ design skills, with increasing complexity and ambiguity. The design courses are also an excellent vehicle for promoting important graduate attributes such as teamwork and communication. The knowledge and techniques from these courses are also applied to other courses in the curriculum that contain design components, reinforcing design practice and ensuring consistency of methodology.

Continual monitoring of student performance, feedback and satisfaction will ensure that the program remains flexible enough to meet the needs of students now and in the future.

Acknowledgements

The authors would like to thank the NSERC Chairs in Design Engineering for their support and the Lassonde School of Engineering for support of the design projects.

References


