Diversify First Year Engineering Students' Problem Solving Experiences – Implications from Engineering Workplace Research

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***Abstract* – Previous studies show that engineering workplace problems are different from textbook or classroom problems in many ways. To better prepare students with workplace competencies, it is important for engineering educators to design meaningful learning experience and actively engage students in solving real world engineering problems. Based upon research on problem solving and the author's own teaching experience in the first year engineering program, this study proposed several recommendations regarding how to diversify students' problem solving experiences and better equip students with real world problem solving knowledge and skills.**

Index Terms – Problem solving, Real world engineering, Students' experience

INTRODUCTION

As previous research has indicated that many students come to engineering without a clear picture of what engineering is and what engineers do [1] [2], one important objective of the first year engineering program is to help students develop a better understanding of engineering as a profession and prepare students with fundamental engineering knowledge and skills by exposing students to engineering problems and actively engaging students in problem solving activities.

Research on problem solving suggests that problems can be classified into different types, for instance, troubleshooting, decision making, design and logic problem, based on their attributes such as abstractness and structure [3]. Recent studies further point out that among those problems, well-structured ones are commonly used in engineering classrooms, yet in the workplace, majority of the engineering problems are ill structured and students who have opportunities to practice engineering in the real world experience workplace problem solving in different ways [3] [4] [5]. Therefore this study aims to offer recommendations to bridge the gap between workplace engineering and classroom engineering education.

After many years of efforts made by engineering educators and researchers to improve the first year engineering program, it is evident that now students have access to a variety of problem solving and learning activities that are carefully designed to help them develop better engineering skills. However, it is still largely unknown what types of problems students are provided with and what kinds of problem solving experiences students have in the first year engineering classrooms. Considering that many students enter the college without much knowledge of what engineering is, the introductory engineering courses they take may influence their conceptualization of engineering. Therefore, the first year engineering program has the opportunity to shape students' perceptions of engineering and promote students' passion to pursue engineering as their future career. So it is imperative for engineering educators to help students understand the nature of engineering work and develop real world problem solving knowledge and skills. Drawing upon research on workplace problem solving and the author's own teaching experience in Purdue's first year engineering program, this study responds to the recent calls for a transformation in undergraduate engineering education to better prepare engineering students with real world engineering competencies [6] by proposing several suggestions to better design the first year engineering curricula and students problem solving experience, including development of strategies to understand students' prior problem solving experiences, classification of classroom problems and problem solving experiences into different types.

REVIEW OF LITERATURE ON ENGINEERING WORKPLACE PROBLEMS

Workplace problems are different from traditional textbook or classroom problems in many aspects. Jonassen (1997) described the problems students often encounter in engineering classrooms as "well-structured problems" [7]. Those problems usually have well-defined scopes and specifications and a standard solution [7] [8] [9]. In contrast, workplace problems are typically "ill-structured problems" because they are vaguely-defined, possess unknown parameters, and can be solved in multiple ways [7] [8]. By interviewing more than one hundred professional engineers, Jonassen, Strobel and Lee (2006) summarized the unique attributes of workplace problems, illustrating how they differ from classroom problems, such as workplace problems have conflicting goals, various solutions, and different types of constraints; they then pointed out that

solving workplace problems requires comprehensive collaboration and teamwork [4]. Korte, Sheppard and Jordan (2008) interviewed 17 newly hired engineers and identified four subthemes describing the problem solving process in engineering workplace: "organize, define, and understand a problem; gather, analyze, and interpret data; document and present the results; and project-manage the overall problem-solving process" (p. 6) [10].

RESEARCH ON STUDENTS' EXPERIENCES OF WORKPLACE PROBLEM SOLVING

Although much research has been conducted on the subject of workplace problems, how such problems are experienced and understood by college engineering students is still unclear. As students are expected to be problem-solvers in the engineering workplace after graduation, it is important that they understand the nature of the problems they will encounter and the specific challenges they will face in the real world.

In order to better understand students' experience of workplace problem solving, I interviewed 22 engineering Co-Op students about their problem solving experiences and explored: what are the different ways in which engineering students experience workplace problem solving? In order to answer this question, I conducted a phenomenographic analysis on the interview transcripts to capture the variation in students' experiences. The analysis results show that students experienced workplace problem solving in six different ways, which are: 1) workplace problem solving is following orders and executing the plan; 2) workplace problem solving is implementing customers' ideas and satisfying customer needs; 3) workplace problem solving is using mathematical and technical knowledge and skills to solve technical problems; 4) workplace problem solving is consulting different people and collecting their inputs; 5) workplace problem solving is using multiple resources to draw conclusions and make decisions; 6) workplace problem solving is exploration and freedom [5].

PROBLEM SOLVING COMPONENTS IN THE FIRST YEAR ENGINEERING COURSES

Previous research on the first year engineering courses indicates that there is a strong emphasis on incorporating real world examples into classroom education and teaching students problem solving strategies [11] [12]. However, it is still not clear what kind of problems are used as examples in the classrooms and how much those examples resemble problems that engineers encounter in the workplace, let alone what kind of problem solving experience students have. A brief review of the studies on first year engineering shows that many efforts have been made to include authentic problems in teaching. Currently, design problem is probably one of the widely used problems in first year classrooms to teach students engineering concepts and problems solving skills [13]. Other types of problems and activities, such as model eliciting activity (MEA) – an mathematical modeling activity [14] and Disassemble/Analyze/Assemble (DAA) activities [15] [16] were also used by engineering educators. .

IMPLICATIONS AND RECOMMENDATIONS FOR THE FIRST YEAR ENGINEERING PROGRAM

As a former graduate teaching assistant, I had been working in Purdue's first year engineering program for three consecutive semesters and thus possess the firsthand knowledge of how engineering is taught and learnt in the classroom setting. Based upon research on problem solving and my own observation, I have made several suggestions of improvement to the first year engineering program.

First, most students come to engineering with some previous problem solving experiences they gained from K-12 education and the first year engineering program should help students build on those experiences to acquire additional problem solving knowledge and skills. In order to achieve this goal, it is recommended that the instructional team could design a survey or test to get an insight into students' prior problem solving experiences and require all first year engineering students to complete the survey or test at the beginning of the semester. Based on the results obtained, the instructional team could develop and incorporate problems that students don't have much experience with into homework, in-class activities and exams, with the purpose of exposing students to a broader range of problem solving experiences. For example, if most students experience problem solving as mathematical calculation in their previous education, the instructional team might want to create some problems that encourage students to interact and consult with people to find solutions. If students don't have experience in solving ill-defined problems, they should be given more opportunities to work on problems that are not well-defined and require them to collect information to better define problems. During the semester, the instructors and TAs should carefully observe students' progress and ask students questions such as: which type of problems are you mostly comfortable with? Which type of problems do you feel most challenging to deal with and why? Then based on students' answers, the instructional team could adjust homework problems and in class activities to meet student needs and develop corresponding teaching strategies to help students overcome difficulties in problem solving.

Second, it is recommended that current homework problems, in class activities and exam problems could be classified into different types: e.g. technical/mathematical problems, problems that require collecting other people's ideas. By calculating the frequency and summarizing the information, the instructional team would have a better idea of the different types of problems students solve in the first year engineering program. This allows the instructional team to easily identify areas for improvement: e.g. which types of problem appear less frequently in the classroom but

should be given more attention? To make sure students can experience different types of problem solving in a progressive way, homework problems and in class activities should be designed in a manner that first encourages students to solve some well-defined problems and gradually move to ill-defined ones.

Third, during the lecture, instructors could introduce the different kinds of workplace problems to students and explain to students that there are different ways to solve problems. To help students develop a better understanding of engineering workplace, the instructors could incorporate examples of real world problems into teaching and invite professional engineers to come to the classroom and share their problem solving experiences with the class.

Fourth, as many students felt that classroom problems were more "theoretical" and "experimental" and they couldn't see the impact of their work, one way to change students' perceptions and experiences is to provide students with opportunities to collaborate with local communities to help people solve a real problem. This will benefit students in many ways: e.g. students will be able to interact with a variety of stakeholders and understand real world constraints and limitations that they won't be aware of if they are just sitting in the classroom.

CONCLUSION

Research on problem solving suggests that there are different types of problems present in engineering workplace, and students experience workplace problem solving in different ways. Therefore, to better prepare students with the knowledge and skills required in the workplace, it is suggested that engineering educators could diversify students' problem solving experiences in the first year engineering classrooms. For example, by purposefully engaging students in problem solving activities that require extensive collaboration, engineering educators can help students develop better communication and team work skills. In addition, knowing students' prior problem solving experience and being aware of the classification of problems would also help engineering educators determine students need and design corresponding learning experience.

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