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Engineering Students’ Perceptions of Workplace Problem Solving

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Engineering Students' Perceptions of Workplace Problem Solving

Abstract

Research shows that workplace problems are different from traditional textbook or classroom problems because they are ill-structured and complex in nature. However it is unclear whether engineering students, who will become professionals in the workplace after graduation, understand those challenges within real world problems and possess the required competencies. Therefore in this study, we explored workplace problem solving from engineering students' perspectives. Based on the literature review, we designed a survey and sent the survey to engineering students who have participated in the Co-Op program. Analysis of the quantitative data shows that students felt they were moderately prepared to work in the Co-Op program and they developed better engineering knowledge and skills from getting involved in real world engineering. In general, students believed that workplace problem solving was more difficult and challenging than classroom problem solving in a number of aspects.

Introduction

Workplace problems are different from traditional textbook or classroom problems because they are ill-structured and complex in nature. Research shows that engineers need a wide range of knowledge and skills in order to succeed in workplace problem solving. However, it is unclear whether engineering students, who will become professionals in the workplace after graduation, understand those challenges within real world problems and possess the essential knowledge and skills required by problem solving. Motivated by a desire to better understand students and prepare them for real world engineering practice, this study aims to explore students' perceptions of workplace problems solving.

As previous research points out that educational programs such as co-op and internships provide opportunities for students to experience engineering in the workplace and prepare them with workplace competencies, we believe students who have participated in such experiential learning programs should have a better understanding of workplace problems. As an initial step to explore students' perceptions of real world problem solving, we decided to focus this study on students who have participated in the Co-Op program.

The research questions guiding this study are: 1) To what extent are students prepared for the Co-Op program and real world engineering? 2) How do students perceive the difficulties and challenges in real world engineering problem solving? 3) How does students' Co-Op experience influence their perceptions of workplace problem solving?

Literature review

Workplace problems are different from traditional textbook or classroom problems. In literature, researchers have described workplace problems as "ill-structured problems"[1] or "wicked problems"[2]. By interviewing over one hundred professional engineers, Jonassen, Strobel, and Lee (2006) found that workplace problems are ill-structured because they have, among other things, conflicting goals, various solutions, and different types of constraints; they then pointed out that solving workplace problems requires comprehensive collaboration and teamwork[1]. Buckingham Shum, MacLean, Bellotti, and Hammond (1997) listed some important features of wicked problems, noting that they:

- Cannot be easily defined so that all stakeholders agree on the problem to solve.
- Have no clear stopping rules.
- Have better or worse solutions, not right and wrong ones.
- Have no objective measure of success.
- Require iteration - every trial counts.
- Have no given alternative solutions - they must be discovered.
- Require complex judgments about the level of abstraction at which to define the problem
- Often have strong moral, political, or professional dimensions that cannot be easily formalized[3] (p. 274).

A complete summary of the unique attributes of workplace problems and classroom problems, illustrating how they differ from each other is presented by Regev, Gause, and Wegmann (2008) and shown in table 1[2] (p. 87).

Experience	Classroom	Workplace
Problem definition	Well defined.	Ill-defined. Half of the challenge is just defining the problem. Often, in fact, a solution is implied by a mutually acceptable definition.
Problem approach	Strongly indicated by most recently presented classroom material. Problems tend to be carefully compartmentalized to reinforce specific methodologies.	Few hints as to how to approach the problem. In small companies, there will likely be no one to go to for help. You will, nearly always, be required to go beyond past studies and methods and may be required to invent new methods.
Problem solution	Professor always knows the solution. If the problem is an odd numbered problem, the solution is in the back of the book.	A solution to the problem will only be apparent when it has been accepted by management.

Problem scope	Many problems are "scoped" so that they can be solved by one person (student) in a few days or weeks.	The scope of the problem will not be recognized and you will be expected to produce the resources and time necessary to achieve the end result. In general, problems require a team of several people working over a period of many months.
Social environment	Working as an individual with implied competition.	Working as a team member, cooperation being essential.
Information levels	Accurate, well defined, explicitly stated.	Vague, unrecognizably ambiguous. Occasional hidden agendas. Credibility of the source and timeliness of the information is always an issue.
Solution methods	Given by an authority figure, usually to reinforce material recently presented. Veracity and efficacy never an issue.	May have to invent a new method as part of the problem solving process. Authority figure often projects his/her solution as the method of approach.
Design team	Same group of members from beginning to end of project (14 weeks).	New members join the team and old, experienced members leave the team, sometimes at the worst possible times.
Stability of problem statement	Once stated, the problem statement is rarely, if ever changed.	The problem statement changes frequently as new information becomes available and new clients are brought into the picture.
Information channels	Heavy use of well-documented, written form.	Some documentation but much critical information is conveyed in "expedient" verbal (sometimes, off-hand) forms such as one-on-one meetings, telephone and other informal conversations.
Conflict	Conflict with authorities is strongly discouraged. Conflict with colleagues is best ignored as it will go away in 15 weeks.	Conflict with authorities is strongly discouraged. Conflict with colleagues is best ignored as it will go away by project end.

Table 1 Comparison between workplace problems and classroom problems[2] (p. 87)

Although much research has been conducted regarding workplace problems, how those problems are perceived and understood by college engineering students is still largely unknown. Since students are expected to be problem-solvers within the engineering workplace after graduation, it is important that they understand the nature of those problems that they will encounter and the specific challenges they are going to face in the real world.

Not many researchers have investigated students' perceptions of engineering workplace problem solving. Some of the existing studies we have found suggest that students might not have a good understanding of engineering workplace. For example, Jocuns, Stevens, Garrison, and Amos (2008)'s study indicates some students graduated from engineering without a clear idea of what the actual workplace will look like[4]. Similar findings are shared in the work presented by Matusovich, Streveler, Miller, and Olds (2009). Their qualitative study over a four year period found three out of ten participants remained uncertain about what engineering is and what it would mean to be an engineer at their third or fourth year in undergraduate study[5].

Because workplace problems vary from classroom problems and engineers need a wider range of knowledge and skills in order to solve workplace problems, it is important for engineering educators to ensure that their students are properly prepared with the required knowledge and skills. Brumm, Hanneman, and Mickelson (2005) proposed that one of the best ways to prepare students with workplace competencies is experiential education[5]. They stated that "experiential education can be broadly defined as a philosophy and methodology in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, and clarify values" [6] (p. 2). Brumm et al. further narrowed down this definition, arguing that "it is work experience in an engineering setting, outside of the academic classroom, and before graduation" [6] (p. 2) and suggested that "Engineering experiential education programs, such as cooperative education and internships, present the best place to directly observe and measure students developing and demonstrating competencies while engaged in the practice of engineering at the professional level" [6] (p. 2).

One typical experiential learning program is co-op program. Garavan and Murphy (2001) defined cooperative education as "a unique form of education and experiential learning, which integrates classroom study with paid, planned and supervised work experience in the private and public sector" [7] (p. 281). They summarized previous literature and listed five outcomes of cooperative education program that employers think would be valuable to students: "1) Enhanced student self-confidence, self-concept and improved social skills. 2) Enhancement of practical knowledge and skills. 3) Enhanced employment opportunities. 4) Attainment of necessary skills to supplement theoretical training. 5) Enhancement of the induction process when the student joins the labor market" [7] (p. 282).

However, although previous research indicates that experiential education benefits students in differing ways; it is still not clear how and in what aspects experiential education shapes students' perceptions and understanding of engineering workplace problems. Therefore, in this study, we wanted to explore how students participating in experiential learning program perceive workplace problem solving.

Research questions

The research questions guiding this study are: 1) To what extent are students prepared for the Co-Op program and real world engineering? 2) How do students perceive the difficulties and challenges in real world engineering problem solving? 3) How does students' Co-Op experience influence their perceptions of workplace problem solving?

Method

In order to answer our research questions, we designed a survey in this study based on our literature review. After the survey was developed, we contacted the director of the Co-Op program and with the assistance of the director, the survey was sent out to engineering undergraduates who participated in the Co-Op program at one Midwestern University. In total, 93 students completed the survey.

Analysis and Results

1) Participant information

In total there were 93 participants in our study, 65 of them were male and 28 were female (Table 1). All of the participants were second year and above students (Table 2) from various departments in the college of engineering (Table 3). The majority of our participants were white (Table 4).

Gender	Number of responses	Percentage
Male	65	70%
Female	28	30%

Table 1 Gender distribution of sample dataset

Academic year	Number of responses	Percentage
Second year	21	23%
Third year	32	34%
Fourth year	23	25%
Fifth year and above	17	18%

Table 2 Information about participants' academic years

Engineering Major	Number of responses	Percentage
Mechanical engineering	38	41%
Chemical engineering	15	16%
Electrical and computer engineering	12	13%
Biomedical engineering	8	9%
Aeronautics and astronautics engineering	7	8%
Civil engineering	5	5%

Industrial engineering	5	5%
Construction engineering and management	1	1%
Material engineering	1	1%
Nuclear engineering	1	1%

Table 3 Information about participants' engineering majors

Ethnicity	Number of responses	Percentage
White	75	81%
Asian	14	15%
Black or African American	1	1%
*Others	3	3%

*Others: mixed

Table 4 Information about participants' ethnicity information

2) Summary of participants' Co-Op experience

Most of our survey participants have already completed at least one Co-Op session, while 18 students were still in their first Co-Op session when the survey was distributed (Table 5). Majority of our participants (86%) worked for large sized companies and few (15%) worked for smaller sized companies (Table 6). During their Co-Op experience, students got involved in all different kinds of work, with problem solving and data analysis being the two most common ones (Table 7).

Number of Co-Op sessions completed	Number of responses	Percentage
0	18	19%
1	15	16%
2	23	25%
3	16	17%
4	9	10%
5	12	13%

Table 5 Summary of the number of Co-Op sessions completed by participants

Size of the company	Number of responses	Percentage
Large (More than 500 employees)	80	86%
Midsized (201-500 employees)	8	9%
Small (50-200 employees)	3	3%
Mini/Start-up(less than 50 employees)	3	3%

Table 6 Summary of the sizes of the companies that participants worked for

Type of work	Number of responses	Percentage
Problem solving	79	85%
Data analysis	70	75%
Design	56	60%
Failure engineering (Trouble shooting)	43	46%
Research and develop	41	44%
Process engineering	36	39%
Manufacturing	35	38%
Quality control	31	33%
Consulting	8	9%
Human resource and training	5	5%
*Others	13	14%

*Others include: validation, IT, documentation, sourcing, estimating, testing, enterprise resource planning, inspection, project management, maintenance, product engineering, and demolition

Table 7 Summary of the types of engineering work students got involved in

3) Analysis of students' preparation for the Co-Op work

In the survey, we asked students to rate in each knowledge and skill area based on a 1 to 6 scale: 1) how much they feel their academic courses prepared them to work in their Co-Op program, considering 1 as "did not prepare me at all" and 6 as "prepared me very well" 2) how much they have gained from their Co-Op experience, considering 1 as "not at all" and 6 as "very much" 3) how competent they feel when they compare themselves to engineers they worked with, considering 1 as "not very competent" and 6 as "very competent".

From the result (Table 8) we can see that, in general, students agreed that they were moderately prepared by their course work for the Co-Op problem solving and they felt they were least prepared with knowledge of industrial standards, yet the Co-Op program helped them get a better knowledge of this area. The Co-Op education also promoted students' confidence in working in industry, provided them with more insights into the engineering profession and enhanced their knowledge and skills in many areas (ratings of most items were around five points) such as communication skills, problem solving skills and technical knowledge. Overall, students were confident with their engineering knowledge and skills, as all of the ratings were above four points when asked to compare themselves with engineers they worked with.

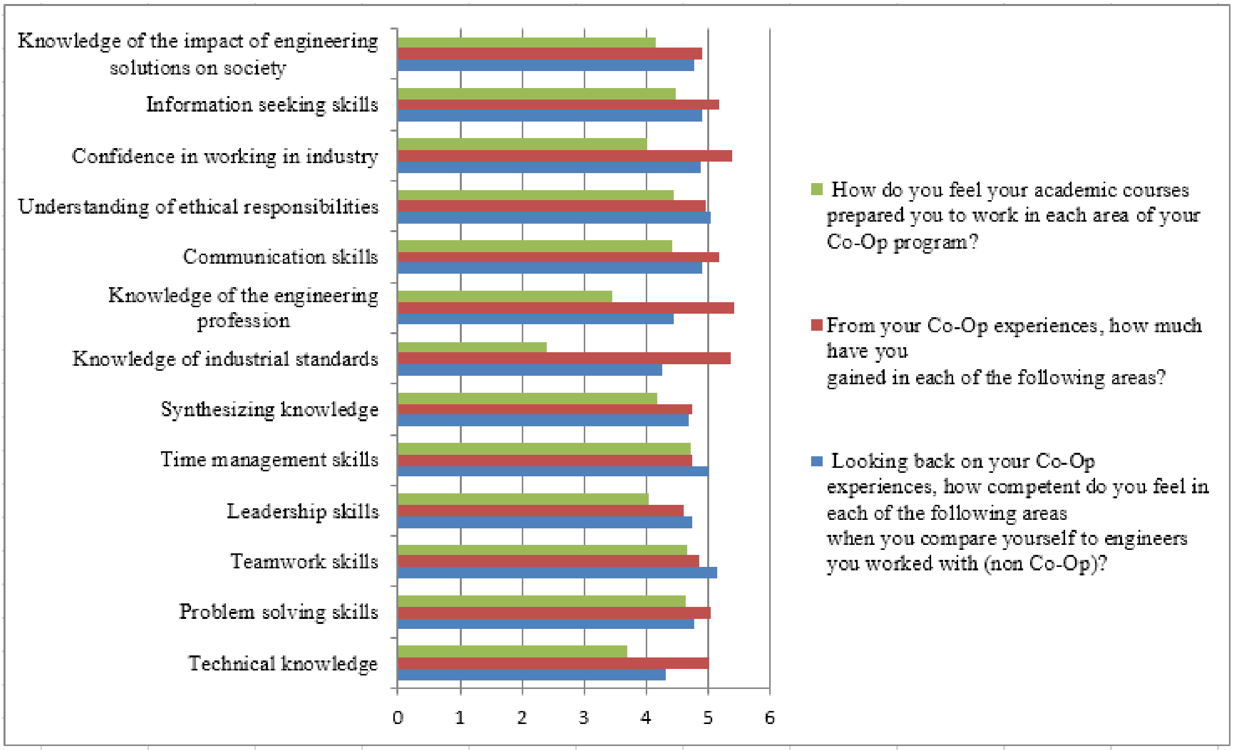

Table 8 Comparison of students' ratings in knowledge and skill areas

Because the Co-Op work environment is different from classroom environments, it might take time for students to adjust themselves for working in a new industrial setting. Therefore, in the survey, we asked students to rate how difficult they felt it was to adapt to Co-Op work in different areas, considering 1 as "not difficult at all" and 6 as "very difficult". The result is summarized in Table 9. Notice that students found communication with clients was the most difficult one while they found it least challenging to adjust themselves to the culture of the company and pace of work.

Item	Mean	Standard deviation
Communication with clients	4.53	2.11
Project management	3.8	1.56
Tools and software	3.66	1.39
Technical demands	3.65	1.13
Communication with colleagues	3.03	1.35
Pace of work	2.71	1.26
Culture of the company	2.28	1.16

Table 9 Summary of students' ratings in adjustment to Co-Op work

4) Analysis of students' perceptions of difficulties and challenges in workplace problem solving

Based on the literature review, we summarized major differences between workplace problem solving and classroom problem solving. In the survey, we asked students to rate each difference from 1 to 6, considering 1 as "problems worked in classroom were much more difficult / challenging", 6 as "problems worked in the Co-Op were much more difficult / challenging". The result is summarized in Table 10. In general, students felt that solving workplace problems were slightly challenging, as most of the ratings were above three and below four. The most difficult part of solving workplace problems reported by students was to deal with the unstableness of the problem, as it was rated 4.67, the highest score in the table.

Difference between workplace problem solving and classroom problem solving	Mean	Standard deviation
How stable was the problem (changes caused challenges)	4.67	1.14
How problems were defined	3.95	1.63
How information was gathered and analyzed	3.9	1.33
How information was conveyed and documented	3.89	1.46
How the scope (e.g. time frame, constraints) of a problem was determined	3.83	1.65
Social environment	3.76	1.29
How success was measured	3.73	1.42
How different methods and tools were used to represent problems	3.72	1.27
How methods were chosen to solve a problem	3.7	1.33
How much you had to rely on your past experience to be effective	3.58	1.5
How problems were solved	3.42	1.59
How conflicts were resolved	3.37	1.27
How problems were approached	3.36	1.42
How your teams were built	2.96	1.2

Table 10 Student's perceptions of difficulties in workplace engineering problem solving

5) Analysis of how the Co-Op program affects students' perceptions of workplace problem solving.

In the survey, we asked students to compare their perceptions of workplace engineering prior to their Co-Op experience to their understanding after they experienced the Co-Op and rate the following statements based on the scale of 1 to 6, where 1 was "strongly disagree" and 6 was "strongly agree". The results are presented in Table 11. In general, the Co-Op program helped students get a slightly better understanding of the complexity of workplace problem solving, as most of the items were rated between three and four. It should be noticed that most students tended to strongly agree that the Co-Op program helped them to realize that engineering requires more interdisciplinary competencies, as this item was rated as 4.51, the highest one among all ratings.

Statement	Mean	Standard deviation
Engineering requires more interdisciplinary competencies than I thought.	4.51	1.36
The work environment is much more complex than I thought.	3.91	1.61
The impact of engineering work is much greater than I thought.	3.86	1.52
The culture of the company is different from what I expected.	3.85	1.5
The problems engineers solve are much more complicated than I thought.	3.81	1.45
Engineers face more difficulties than I thought.	3.74	1.37
Engineers need more skills than I thought.	3.68	1.38

Table 11 Students' perception change after Co-Op program.

To better understand how students' Co-Op experience might change their perceptions of workplace problem solving, we preformed regression analyses of the number of Co-Op sessions students completed on students' ratings on each item in table 10 and table 11. We wanted to explore whether increased experiences in Co-Op might have an impact on students' response. The model is formulated as follows:

$$Students'rating = \beta_0 + \beta_1 NumberofCo-OpSessionsCompleted +$$
$$\beta_2 Gender + \beta_3 AcademicDiscipline + \beta_4 Ethnicity$$

where Gender, Academic Discipline and Ethnicity are coded as categorical variables and the Number of Co-Op Sessions completed is treated as the continuous variable

Besides the number of Co-Op sessions completed by students, we also included gender (female vs male), academic discipline (mechanical vs non-mechanical), ethnicity (white vs non-white) as predictors in our model because although they were not the factors we were interested in, they might have a potential effect on the response variable. Notice that we choose to compare mechanical engineering students vs non-mechanical engineering students because 41% of our respondents were from mechanical engineering and the number of students in other disciplines was too small to perform pairwise comparison analysis between all different disciplines. The reason why we decided to compare white vs non-white is similar, as 81% of our sample population were white students.

We used GLM procedure in SAS to perform all statistical analyses and the LSMEANS procedure to compare the means of responses by different groups, e.g. white vs non-white. After running all regression analyses on the 14 items in table 10 and 7 items in table 11, we found that the number of Co-Op sessions students completed is a significant predictor for students' response in five items (Table 12), when controlling the effects from other predictors. It was found that the number of Co-Op sessions students completed is negatively correlated with students' ratings in all those five items, which means the more sessions students complete, the less difficult they think workplace problem solving is.

Response variables (ratings from 1-6)	Estimate of correlation coefficient	P value
How problems were solved	-0.2057	0.0462
How information was conveyed and documented	-0.2557	0.0063
The problems engineers solve are much more complicated than I thought.	-0.1963	0.0217
The culture of the company is different from what I expected.	-0.3596	0.0001
Engineering requires more interdisciplinary competencies than I thought.	-0.2382	0.006

Table 12 Regression analysis on students' responses (effect of the number of Co-Op sessions completed)

Another interesting finding is that ethnicity is a significant predictor for students' response in seven items (Table 13). In general, non-white students tended to score higher than white students in six items, which means they felt workplace problem solving were more difficult, compared with classroom problem solving and their previous thoughts. The only item that white students rated significantly higher than non-white students is the difficulty to adjust themselves to the culture of the company.

Response variables (ratings from 1-6)	White	Non-white	P value
How the scope (e.g. time frame, constraints) of a problem was determined	3.494361	4.642541	0.0073
Social environment	3.687162	4.411179	0.0305
How conflicts were resolved	3.14991	4.181436	0.0018
How different methods and tools were used to represent problems	3.521794	4.428683	0.0066
The problems engineers solve are much more complicated than I thought.	3.739834	4.817078	0.0023
Engineers need more skills than I thought.	3.492859	4.273713	0.0281
The culture of the company is different from what I expected.	4.044267	3.27754	0.0387

Table 13 Regression analysis on students' responses (effect of ethnicity)

We also found that gender and academic discipline to be significant predictors in two and one items, respectively. Males rated the difficulty level of "How problems were approached" higher and less agreed with the statement "The impact of engineering work is much greater than I thought", compared with their female counterpart. And mechanical engineering students agreed more with the statement "The problems engineers solve are much more complicated than I thought", compared with non-mechanical students.

Response variables (ratings from 1-6)	Male	Female	P value
How problems were approached	3.749268	3.105909	0.0492

The impact of engineering work is much greater than I thought.	3.766659	4.605033	0.0161

Table 14 Regression analysis on students' responses (effect of gender)

Response variables (ratings from 1-6)	Mechanical engineering students	Non-mechanical engineering students	P value
The problems engineers solve are much more complicated than I thought.	4.669375	3.887537	0.0067

Table 15 Regression analysis on students' responses (effect of academic discipline)

Discussion & future work

In this study, we first explored students' perceptions of their preparedness for the Co-Op work. In general, we found that students felt they were moderately prepared by their course work to work in the Co-Op program, except that many students reported they needed more knowledge of the industrial standards. Another major challenge students met in the workplace was to communicate with clients. Those findings indicate that engineering educators need to better prepare students with knowledge and skills for workplace engineering. Students also indicated that the Co-Op experience helped them develop better engineering knowledge and skills, such as knowledge of industrial standards, communication skills, which confirms findings from previous research that cooperative education is a truly valuable experience to students[7].

The focus of this study is to examine students' perceptions of difficulties and challenges in workplace problem solving. Overall, we found that students believed workplace problem solving was somewhat more difficult than classroom problem solving and the Co-Op program did help them get a better understanding of engineering in the workplace. We also used regression analyses to test whether more involvements in Co-Op work would affect students' perceptions of workplace problems. And we did find that in some areas, the more the students get engaged in the Co-Op work, the less difficult the students perceive workplace problem solving is. We think the reason would be that when students are exposed to workplace problems for a longer time, they gradually get used to working in the Co-Op thus feel workplace problems less difficult. For future research, we want to test the survey on students without any experiential learning experience and compare the results with findings from this study.

Another discovery from our study is that, ethnicity was found to be a significant predictor for students' perceptions of the difficulty of workplace problem solving in several aspects. The analysis result shows that non-white students tend to find workplace problem solving to be more challenging/difficult. Due to the limited sample size, it is hard for us to draw a firm conclusion at this point. For future research, we plan to expand our sample size and use both qualitative and quantitative methods to further investigate how and why factors, such as ethnicity, citizenship, gender and academic disciplines might impact students' understanding of workplace problem solving.

Another limitation of our study is the lack of supervisor evaluation to match against students' perceptions. So in the future, we want to modify the survey and send to all Co-Op supervisors in order to compare the results with students' perceptions.

Conclusion

In the Co-Op education program, students participate in various types of engineering work. In general, students believed that workplace problem solving was more difficult and challenging than classroom problem solving. Our study demonstrates that students develop a better understanding of engineering workplace and better engineering knowledge and skills from getting involved in real world engineering and they are confident in practicing engineering in the real world.

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