Integrating Professional Practice in the Engineering Curriculum: BE/ME Chemical Engineering Students' Experiences in Industry Placements

Homero Murzi[a]; Andrea Mazzurco[b], and Beverly Coulter [c].
Virginia Tech[a], Swinburne University of Technology[b], The University of Queensland[c]
Corresponding Author Email: hmurzi@vt.edu

CONTEXT Engineering schools are tasked with the challenge of preparing engineering graduates who are equipped with competencies that satisfy industry expectations and Engineers Australia requirements. This task is particularly challenging because it is difficult to replicate industry-like situations in engineering classrooms. To address this challenge, the Bachelor of Engineering (Honours)/ Master of Engineering (BE/ME) at the University of Queensland (UQ) offers a six-months placement experience which provides the students with an opportunity to engage in industry or research before they graduate, and to apply the knowledge acquired on placement in their last year as UQ engineering students. Although the program seems to be successful, there is no research done or data collected on the program that can provide feedback to the School about the program strengths, improvement areas, and the learning gains the students have by participating in the experience.

PURPOSE The purpose of this research is to investigate the daily work experiences of chemical engineering students in BE/ME placements and the learning gains resulting from participating in it.

APPROACH We used a qualitative study design. For this pilot study, we conducted interviews with two BE/ME Chemical students after participating in the placement program. We developed the interview protocol based on three theoretical frameworks: (i) the PPIR framework by the Warren Centre that explains what professional engineers should be able to do; (ii) the boundary spanning framework that fully unpacks aspects of working with people within an engineering organization; and (iii) the Engineers Australia Stage 1 and 2 Competencies that provide competencies that align with and expand many aspects of the aforementioned frameworks. Interview transcripts were analysed using qualitative data processing software.

RESULTS Analysis of the data identified three main emergent themes. First, students recognised that working and collaborating with other people - rather than siting in isolation doing calculations- is a major part of the engineering practice. Second, students realized the importance of understanding troubleshooting processes and all the other implications of design. Finally, students understood the importance of communication as a key component of engineering, especially in relation to the emotional aspects of working in industry.

CONCLUSIONS This study provides evidence on the students' experience in the placement program. Students recognised that the University has not been able to provide them with learning experiences that were comparable to their placement. Engineering programs need to invest more resources in the development of professional skills like communication, teamwork, and the management of human resources since the preliminary evidence from this study suggests such professional skills are not yet a main focus of engineering education.

KEYWORDS

Work-Integrated Learning, Placement, Communication, Collaboration, Professional Skills, Boundaries.

This work is licensed under the Creative Commons Attribution 4.0 International License. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/

Introduction

Engineering schools are tasked with the challenge of preparing engineering graduates who are equipped with competencies that satisfy industry expectations and Engineers Australia requirements. This task is particularly challenging because it is difficult to replicate industry-like situations in engineering classrooms. Yet experiences in the workplace, provide one of the most significant learning sources (Lucas, Cooper, Ward, & Cave, 2009). Hence, Universities around the world have been incorporating placement programs in their engineering curriculums to make students more competitive and ready for the workforce. However, Universities need more information on the performance of the placement programs to maximize the success of these types of educational interventions (Hackett, Martin, & Rosselli, 1998).

To address this challenge, the Bachelor of Engineering (Honours)/ Master of Engineering at the University of Queensland offers a six-months placement experience which provides the students with an opportunity to engage in industry or research before they graduate and to apply the knowledge acquired on placement in their last year as UQ engineering students. Although the program seems to be successful, there is no research done or data collected on the program that provide feedback to the Engineering Faculty about the program strengths, areas of improvement, and the learning gains the students have by participating in the experience.

In order to understand the placement experience and learning gains of students in the BE/ME program, we developed a mixed-method sequential study design to collect several sources of data on UQ chemical engineering students that participated and will participate in the program. Specifically, we want to answer the following two research questions:

1. What was the nature of the students' daily work?
2. How has the placement experience impacted their professional development?

Answering these research questions will enable us to paint a very rich and thorough picture of students' experiences during their mandatory industry/research placement, which in turn will allow us to further enhance the experience of future students and provide evidence of the usefulness and value of such types of activities for students, academics, and employers.

In this paper, we report preliminary results from our initial qualitative pilot study. We interviewed two students a few months after the placement and present emerging insights from two of the richest interviews.

Theoretical framework

In this study, we integrated multiple existing frameworks that characterize multiple facets of the professional engineering practice. First we used the Warren Centre's Professional Performance, Innovation and Risk framework (PPIR) (The Warren Centre, 2009). PPIR defines how professional engineers interact with, and respond to, their clients, their professional peers and the community. The framework proposes that professional engineers should be able to 1) be aware of multiple stakeholders, 2) define, scope, and execute engineering tasks in accordance with stakeholders needs, 3) leverage proper resources and knowledge to perform engineering tasks, 4) respond to statutory requirements and public interest, 5) apply risk management approaches, 6) use engineering innovation to enhance an engineering task, 7) apply appropriate management protocols and standards, and 8) follow contractual agreements (The Warren Centre, 2009).

Second, we used the Boundary Spanning framework (Jesiek, Trellinger, & Mazzurco, 2016) that provides a unique lens to understand the realities of engineering work as experienced by practising engineers. The framework fully unpacks aspects of working with people within an engineering organization: including classification of types of boundaries (cultural, educational, demographics, job role, organizational) and boundary spanning activities

(managing information, coordinating, networking, representing and influencing). This framework cuts across and expands many of the dimensions of the PPIR framework.

Finally, we used the Engineers Australia Stage 1 Competencies. Engineers Australia developed competencies that represent the knowledge and skill base, engineering application abilities, professional skills, values and attitudes that must be demonstrated by engineers at the point of entry to the engineering practice.

The integration of the dimensions of the three aforementioned frameworks provided a solid underpinning for the study.

Methods

Although our overall project is a mixed-method sequential study, this paper focuses on the pilot of the first stage of the project (i.e. qualitative interviews). In this section, we describe the qualitative methods used to better understand students' experiences in the placement program. The purpose of this study is to understand what the nature of students' daily work is during the placement experience, and how the placement program impacted their professional development. Since our primary objective is to understand students' experience with the program, qualitative methods that provide rich descriptions are appropriate (Creswell, 2013; Leedy & Ormrod, 2005).

Context

The BE/ME placement course is a key feature of the 5-year, integrated BE/ME program that UQ launched in 2012. BE/ME students undertake a 6-month placement in industry or research in their 4th year of study and then return to university with a wider engineering perspective to complete 5th year masters courses. The BE/ME placement program was first trialled in the School of Chemical Engineering in 2013 when 6 students were placed in industry and research. Today in 2017, there are 27 chemical engineering students enrolled in the placement course and another 36 students enrolled in other engineering disciplines. To date, the experience of students on placement has been monitored via a series of course assessment items including monthly reflective journals and project progress reports. This study allows us to explore the experiences of students in more detail and in a forum outside the formal course assessment schedule.

Participants

The participants of this study were chemical engineering undergraduate students that participated in the BE/ME placement program during the semester 2 2016. For the pilot of this study, we selected two participants from the program and conducted a semi-structured interview. Interviews were conducted with participating students the semester after they participated in the placement program. Participants were invited over email to participate voluntarily in the interview, and there was no compensation for participation. The study secured ethical clearance.

The first participant is Carlos, a male engineering student. He worked for a sugar mills company. His job was to document standard operating procedures for the gas boilers. Maria, the second participant, a female engineering student was placed in a water treatment plant. Maria's job was with the process control and efficiency team working on energy optimisation and chemical optimisation.

Data collection

Data were collected using semi-structured interviews. The interview protocol was informed by the three theoretical frameworks used for this study. In the protocol, students were asked questions about their experience in the placement, their typical duties and responsibilities, and their interactions with others. Students were also provided with an example from the Boundaries Spanning theory and they were asked to reflect on the example according to their placement experience. The interview protocol was tested with other researchers. Those

interviews were not included in this study since the main purpose was to improve the questions and procedures of the final interview protocol. After being selected, students were contacted by email to set a time and place of their preference. The interviews were conducted in a private location. A consent form was developed and read to the students before the interview started. After discussing the consent form the students signed it and the interviewer started audio recording the interview. Interviews lasted no more than 50 minutes.

Data analysis

Thematic analysis methods (Clarke & Braun, 2014; Robson & McCartan, 2016) were used to analyse the data. Thematic analysis is defined by Braun and Clarke (2006) as a method of identifying, analysing, and reporting patterns within qualitative data. According to Robson and McCartan (2016) thematic analysis is a generic qualitative method that allows data to emerge from patterns after doing open coding of the transcripts. Since our interest was to identify, analyse, and report the patterns of the interview data, the use of thematic analysis is appropriate to guide this study. Robson and McCartan (2016) suggest that thematic analysis can be used to better understand "experiences, meanings and the reality of participants" (p. 474).

Following thematic analysis procedures (Braun & Clarke, 2006; Robson & McCartan, 2016), recordings of the interview were transcribed by the researchers to increase familiarization with the data. Pseudonyms were used to ensure anonymity of the participants, and some information like name of courses, professors, and projects were changed. Notes taken during the interview were included when analysing the data to facilitate the development of memos. Codes were developed and two different researchers compared initial codes and agreed on the coding system. Once all parts of the data were coded, codes were grouped based on their similarities into themes. To ensure trustworthiness of the process, two researchers coded independently all the interviews and grouped the codes into the themes developed to establish inter-rater reliability. In instances when codes did not match, researchers discuss the codes until agreement was reached. The MaxQDA software was used to code the interview line by line.

Findings

Investigating students' experiences in the placement program helped identify the way students understood their daily work, as well as, the impact of the program in their professional development. Analysis of the data identified three main emergent themes. First, students recognized that working and collaborating with other people - rather than siting in isolation doing calculations- is a major part of engineering practice. Second, students when solving real problems realized the importance of understanding troubleshooting processes and all the other implications of design. Finally, students understood the importance of communication as a key component of engineering, especially in relation to the emotional aspects of working in industry. In the following section, we elaborate on each theme and provide some examples of students' responses that informed the development of the themes.

Collaboration

Both students recognized the importance of understanding how to work with others during their time in the placement. For the participants, collaboration was something they not only valued but something they needed to learn. They realized the importance of collaboration beyond technical contributions to projects, but on developing long lasting relationships not only with peers at their same levels, but also with operators and people at every level of the company or institution. They recognized the importance of the experience of people in the company even when they didn't have engineering degrees. Carlos commented:

> Learning how to deal and interact with operators is really important and is not related to how good you are regarding technical skills, but rather to how good you are being able to “win” them over.

Maria also commented on how important the operators were for her job:

> The operators actually were almost like family because they really showed me the ropes. They would show me around, give me tours, tell me how to sample, and everything….I actually learnt a lot from operators: they know the practical side so well, and we might have all the head knowledge but our head knowledge might not always match what's really going on in reality, and they do know that.

Furthermore, students saw the importance of social interactions as a bridge to develop specific knowledge about the job. Carlos explained how they created a work group in order to learn more about boilers: “so no one was overly experienced with boilers, so we formed an internal boiler work group and it was the best experience.”

However, students needed to learn the best ways to interact with other people, since they felt that was something they didn’t learn at University. Initially they thought interactions were based on knowledge or practice, however, they realized that interactions were about the social aspects and developing relationships of trust. Maria affirmed:

> So obviously interacting with them is interesting in that when you’re a university student coming into their workplace and asking them a lot of questions, sometimes you can get some heated responses, or some interesting interactions. So you’ve really kind of got to play into that and have a bit of fun with them really, it’s a good way to get them on side.

In sum, it was apparent from the interviews that the placement helped them appreciate the importance of building trust with many different stakeholders in order to being effective in completing their assigned tasks.

Solving real problems

Students also emphasized how different it was to solve problems during the placement as compared to solving problems in the classroom. Participants were not prepared to find high levels of uncertainty in the job, nor to find gaps of knowledge between the theoretical information they had and the on-site application of knowledge they required. As Maria said: “there was a huge difference between learning the theory in the classroom to actually apply knowledge and learn how testing works in reality.” Likewise, Carlos also mentioned:

> It’s not all straightforward, plug and play calculations - so when you actually get a massive data set, and half the data is not right, or it’s not a good period to take data and stuff like that. That’s more real life, and draw conclusions…. but the importance is in just learning how to behave in a professional environment and learning how to react in certain situations when things don't go as planned.

Students also recognised the importance of experience over memorisation of technical knowledge. In Carlos’ words:

> So it took me a while to memorise and to learn and read the procedures and know how to do it accurately. And I could not always get the first time, so I had to always repeat a few times which was very interesting as well, because the way these guys learned how to fix a situation - say the pH is moving out of thing, and they go to the pump that controls the pH regulation, they’ll just tweak it by knowledge of what they’ve done in the past.

To solve problems students realized that the balance between experience and theoretical knowledge is very important. It also made the students very aware of an important aspect of the engineering profession, and that is to be critical when understanding what the best practices are in the discipline. Carlos elaborated:

> …the biggest challenge was probably figuring out what is best practice, that's probably one of the bigger ones, which is why we formed that internal work group. But even still, deciding what's best practice is always a tough thing.

Maria included the importance of effective collaboration with operators as a way to finding the best practices to solve problems:

> I would come to them with a list of things. I said, well, is this the best way to do it? Then we would have conversations about let's do it this way - yeah, no that way's fine. So that's how we decided what best practice was.

Furthermore, for the students, the placement experience was something very valuable that they said they couldn't obtain in a classroom setting. They understood that solving problems had to do also with troubleshooting, uncertainty, and finding alternative ways to apply knowledge. For instance, Carlos realized that problem solving is not only about designing something new, but it also comprises troubleshooting and optimizing existing systems:

> I guess I wasn't really sure what exactly on-site process engineers do, because all the stuff we really deal with in chemical engineering as a degree I would say is mainly design. We deal with this is what this unit is, and how it works, and how you build it. We probably don't deal that much with this unit exists, and it's doing this, it's misbehaving, or, how do we go about increasing the throughput through it?

Overall, this experience changed the way they understood the profession:

> …and I felt like that was really helpful, rather than just sitting on a desk and just having a desk job. I found that skill - I don't know what skill you would call that - but just like the real practical application- to be one of the best I can have as a future engineer (Carlos)

Communication

Another aspect of the placement program that both students talked about was the importance of communication. Students considered that the success of their placement was highly related to how well they could communicate with others; they saw communication as one of the main aspects of the job. Maria commented:

> I'd say a lot of my job was communication, trying to figure out I want this bit of information, how do I get it? So trying to find out where all the things that I needed were. Yeah, talking to the operators, so that's communication.

Also, Carlos commented on communication:

> Yeah I was talking to a lot of people all the time, and because every time you changed site all the people change as well, you've got to do the whole thing all over and get to know who's who and figure it all out again.

Participants expressed that the most important and difficult part was to understand how to communicate with operators. Being able to communicate in their same language led to productive collaboration and working relationships. Carlos explained his process:

> I would go on site, talk to the operators, figure out the draft of the SOP, figure out the best way to do it. Once we decided what the best way to do it was I'd put pictures in of every step, so I had to go around on site, take photographs of everything - which was interesting, trying to find things. Then I'd take it back to the operators, and I'd say 'hey - is this good? Do you understand this? Does this all make sense?'

Carlos also explained how learning to communicate with operators represented a challenge that he could overcome with patience and good communication skills, but was not expecting to spend so much time dealing with these type of situations:

> So one shift will just not even talk to me. I'd come into the operating room, or try and talk to them, just nothing. At that site, I wasn't really getting anywhere, even with the operators that did want to talk to me, we weren't really making any progress, so I went to the plant supervisor there, and I said 'hey, look I'm not making any progress here'. By the time I finished, he was inviting me over to his house for dinner and stuff like that. So it was really a case of I think going to a site like that you definitely have to have thick skin, which I already had. I refereed soccer for five years or so.

Conclusions and Future Research

This paper presented information from a pilot study to better understand the experiences of chemical engineering students in their placement program. After analysing data from two interviews, three main themes emerged across both interviews: (i) the importance of collaboration in the placement experience, (ii) the contingency of solving and troubleshooting problems in the real world, and (iii) the importance of communication in the engineering profession. Although students felt they were prepared technically for the placement experience, they realised that they were missing some training on the importance of these three themes. Students recognised the placement program to be transformative in their professional development, and explained how the placement experience is positively impacting the courses they are taking in their last year.

For the next step in our research we plan to continue the qualitative data collection by interviewing all the students in the placement program cohort in 2016 and 2017. In addition, data collected in this study is helping us develop a survey that will allow us to collect data quantitatively (i.e. pre-and-post test) to determine the specific impact the placement program is having on the student learning and development.

References

Clarke, V., & Braun, V. (2014). Thematic analysis *Encyclopedia of critical psychology* (pp. 1947-1952): Springer.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.

Hackett, R. K., Martin, G. R., & Rosselli, D. P. (1998). Factors related to performance ratings of engineering students in cooperative education placements. *Journal of Engineering Education, 87*(4), 455-458.

Jesiek, B., Trellinger, N., & Mazzurco, A. (2016). *Becoming Boundary Spanning Engineers: Research Methods and Preliminary Findings* Paper presented at the American Society for Engineering Education Annual Conference & Exposition (ASEE), 2016, New Orleans, Louisiana.

Leedy, P. D., & Ormrod, J. E. (2005). *Practical research*: Pearson Custom.

Lucas, W. A., Cooper, S. Y., Ward, T., & Cave, F. (2009). Industry placement, authentic experience and the development of venturing and technology self-efficacy. *Technovation, 29*(11), 738-752.

Robson, C., & McCartan, K. (2016). *Real world research*: John Wiley & Sons.

The Warren Centre, F. A. E. (2009). *Professional performance, innovation and risk in Australian engineering practice*. Retrieved from Sydney, Australia: