Rethinking Engineering Education: Lessons from the Learning Experiences of Early-career Engineers

Miss Yike Li, Shanghai Jiao Tong University

Yike Li received a Bachelor’s degree in Human Resource Management from Nanjing Agricultural University of China (2019), and is studying for a Master’s degree in Higher Education at SJTU. Her research interest includes early-career engineers’ learning experiences and entrepreneurship education.

Jiabin Zhu, Shanghai Jiao Tong University

Jiabin Zhu is an Associate Professor at the Graduate School of Education at Shanghai Jiao Tong University. Her primary research interests relate to the assessment of teaching and learning in engineering, cognitive development of graduate and undergraduate students, and global engineering. She received her Ph.D. from the School of Engineering Education, Purdue University in 2013.

Dr. Zhinan Zhang, Shanghai Jiao Tong University

Dr. Zhinan Zhang is an associate professor at School of Mechanical Engineering Shanghai Jiao Tong University. His research focuses on engineering design driven education.
Work-in-Progress:

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Abstract

More and more scholars have attempted to explore the real-world scenarios from the industry view so as to deepen the understanding of the engineering practice and improve engineering education accordingly. Currently, relevant international research has been increasing on this topic, but empirical research from industry perspective in China is still scarce. This work-in-progress focuses on understanding early-career engineers’ perspective in China using the theoretical framework of Cognitive Apprenticeship (CA), which describes the learning environment in four aspects: the content taught/learnt, the teaching/learning methods employed, the sequencing of learning activities, and the sociology of learning. Moreover, this study employs semi-structured interview to collect data from different industries.

Preliminary findings suggested that the content that new engineers learnt included both the technical and non-technical aspects. The engineers learned through multiple venues, including such as learning by themselves and learning from their mentors. This study will provide practical suggestions for improving engineering education in both China and other similar contexts.

Introduction

Previous studies have indicated that engineering graduates still do not fully reach the requirement of the industry whether from a global or domestic perspective [1], [2],[3]. Therefore, it has become a challenge for universities to enrich the industrial experience of engineering students in the process of school education. Currently, a series of measures have been adopted to enrich students’ practical experience, such as project-based learning and cooperation education, both of which are proved to be effective ways, but there are still some problems, such as low participation of enterprises [4], [5].

Meanwhile, more and more scholars have attempted to explore real-world scenarios from the industrial view and its implications for education. Prior research suggested that most of knowledge, skills, and attitudes (KSAs) used by engineering graduates at work were acquired or deepened in workplace [6],[7],[8]. Engineering education has not fully prepared students for work because there is still gap between the typical problems used in classroom practice and the complex problems in real-world
scenarios [9]. Thus, there is a need for studies to explore workplace learning so as to
deepen engineering educators’ understanding of the engineering practice and improve
engineering education accordingly. Specifically, this study focuses on the perspective
of early-career engineers who graduated within 5 years in China because recent
graduates may be more aware of the differences between the current engineering
training at universities versus at work than engineers who graduated a while ago [10],

In order to explore the process of workplace learning of early-career engineers,
this study asks the following two research questions:
1. What KSAs do early-career engineers acquire or deepen in the workplace?
2. In the workplace, how do early-career engineers acquire or deepen the
corresponding KSAs?

Literature review

The lack of practical experience of engineering graduates concerns the industry
globally. A survey [1] based on British graduates showed that 64% of the enterprises
tended to employ those with 1-2 years’ work experience rather than fresh engineering
graduates. A survey [2] among U.S. industrial representatives also found that about 25% of
employers considered engineering graduates’ abilities, especially problem-solving
ability, worse than ten years ago. Similarly, findings by Cui and Wang [3], found that
in China, 19% of employers thought that engineering education courses did not apply
to real-world engineering practice. As a result, developing KSAs that satisfy the needs
of industry has become a priority in engineering education.

On that basis, workplace learning provides a new perspective. In this study,
workplace learning refers to what KSAs engineers acquire or deepen at work and how
they do so [12], [13]. First, what KSAs do engineers develop in the workplace?
Gainsburg & Rodriguez-Illuesma (2010) pointed out that two thirds of the knowledge
used by engineers is generated in practice, such as the use of specific software [14].
With regard to skills, it can be divided into technical skills and non-technical skills. As
for technical skills, Anderson & Court (2010) found that solving problems in complex
situations for customers was the core value of engineers [15]. Meanwhile, developing
non-technical aspects like communication skill was also considered key to integrate
into a work group or to ensure a smooth work process. For example, Till & Trevelyan
(2008) found that novice engineers spent about 60% of their time interacting with others
in the first year of work [11]. With regard to attitude, it includes qualities such as
responsibility, initiative, loyalty and so on. Male & Bush (2009) considered technical
skills, non-technical skills and attitude all as important aspects of engineering work [16].

Then, how do engineers develop the corresponding KSAs in a workplace? As
indicated by prior research, workplace learning includes formal learning, informal
learning and incidental learning [17], [18]. For example, Lutz (2017) found that the learning experience of professional engineers occurred mostly through typical tasks rather than systematic learning methods [19]. Davis & Vinson (2017) explored the interaction between senior engineers and novice engineers, and pointed out that the guidance provided by mentors was often formalistic instead of valuable [20]. Korte (2009) concluded that the establishment of interpersonal relationship is the key for individual to quickly learn something and to integrate into the organization [21]. Moreover, reflective discussions were also an important learning method when engineers could not fully map the current problems to existing technical models [18], [22].

**Theoretical framework**

Cognitive apprenticeship is a learning environment design theory, it aims at exposing learners to the real-world scenarios to cultivate learners’ advanced ability thus helping individual’s gradual transition from novice to expert [22]. CA framework is composed of four dimensions namely learning content, learning methods, the sequence of learning activities and the sociology of learning. Learning content includes domain knowledge, heuristic strategies, control strategies and learning strategies. Learning methods includes modelling, coaching, scaffolding and fading, articulation, reflection and exploration. The sequence of learning activities includes increasing complexity, increasing diversity and global before local skills. The sociology of learning includes situated learning, culture of expert practice, intrinsic motivation and exploiting cooperation [23]. This study employs cognitive apprenticeship (CA) as the theoretical framework. The two research questions of this study are corresponding to the first two dimensions of the CA framework. Based on the learning content and methods shown in the framework, this study will combine with the interview text to expand the corresponding theme. Moreover, a complete learning process will inevitably include the sequencing of learning activities, and the sociology of learning. Therefore, in order to conduct a more complete discussion on the workplace learning process of early career engineers, this study also analyzes the interview data combined with the last two dimensions of the CA framework.

**Methodology**

To explore the various workplace-learning experiences of early-career engineers, this study adopted one-on-one interviews to collect data. The interview protocol was designed based on the theoretical framework of Cognitive Apprenticeship and consisted of eighteen questions. Sample questions included, “Can you describe a typical day of work briefly,” “What do you think of your growth in the past few years,” and “Can you describe how you communicate with the team or team members”.
The interviewees in this study are early-career engineers who graduated within 5 years in China. Up to now, 6 participants were recruited via professional network and snowballing (Table 1). In the process of purposeful sampling, we intentionally included engineers who were from varied industries, such as civil engineering construction industry, automobile manufacturing industry, software and information technology industry, etc. Moreover, thematic analysis was used to analyze interview transcripts [25].

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>Industry</th>
<th>Work Exp. (yrs)</th>
<th>Cor.Type</th>
<th>Education</th>
<th>Position/Title</th>
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<td>State-owned</td>
<td>Bachelor</td>
<td>Process Engineer</td>
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</tbody>
</table>

**Preliminary findings**

So far, our preliminary qualitative analyses pointed to the insufficiency of current engineering education in China to prepare qualified engineers. The training engineering students received through their education did not bridge well with industries’ needs. Engineering students failed to possess adequate practical skills. Engineering graduates still needed workplace learning to be competent in their working fields.

For example, when asked about how the school education prepared them for work, Carl, a project manager from shipbuilding industry with around 5 years’ working experience, answered:

*Actually, we just learned some theoretical knowledge in school generally. However, it needs more specific knowledge and skills at work.* – Carl

Moreover, it was worth noting that some engineering graduates had insufficient understanding of what they actually do at work, which led to a certain degree of tension at the early stage of work. Therefore, it was of vital importance to prepare students not only technically but also non-technically.

For example, when asked about their growth at work, Allen, a process engineer from automobile industry with 1.5 years’ experience answered:
At the beginning of the work, I didn't know anything about the work content, or even what the whole company was doing. Until I slowly understood the job content, I felt less unsettled. – Allen

a. Learning content

In terms of the content learned in workplace, all the participants mentioned that they acquired hand-on skills, like the use of software. Moreover, they also learned and accumulated the typical ways for solving problems in their specific context. For example, they may get familiar with the established procedures for routine problems during the work process.

The workplace learning of early-career engineers not only involved technical skills but also non-technical aspects. Firstly, engineering students developed their interpersonal skill at the early stage of work because it was key for them to integrate into a work group. Secondly, management ability was learned during the work process. Because with the increase of working years, engineers were no longer solely responsible for technical work, they should know how to coordinate with different kinds of people in a project. Finally, all of the participants mentioned the importance of initiative and responsibility. They also mentioned that school education failed to cultivate the sense of initiative and responsibility of engineering students, which posed a challenge to smooth transition between school and work.

As for technical skills, Bob, an algorithm engineer from IT industry with 1 year’s working experience, mentioned the importance of thoughts for solving problems:

Before doing something, you should think about the whole process generally first, instead of doing it in a rush. Otherwise, when you find that you have taken a detour, you have to come back to think about the problem again, think about it again, and then do it. – Bob

Moreover, Davis, a back-end engineer from IT industry with 1 year’s working experience, highlighted the non-technical aspects of workplace learning:

Communication accounts for at least 40% of our work content. For example, it is the most important part to understand the business requirements in the early stage, how to divide the work in later stage, and how to realize these functions, including the communication between various departments, which is actually a lot of work. – Davis

b. Learning methods

In terms of learning methods, the engineers learned through multiple venues. The most typical way was to learn in the process of completing work tasks, that is, to learn through the accumulation of experiences. Secondly, early-career engineers tended to communicate with their mentors when they were in trouble. The mentors usually referred to those who are more experienced. In addition, to regularly summarize and
reflect on their practices, and imitate similar cases done by others were also effective ways.

For example, when asked about the learning methods in workplace, Allen answered:

*I think to regularly summarize is very important. When you can classify things well and make a good summary, it will be very helpful to solve problems later, say to avoid similar problems. Also, we may learn from some good cases and similar good cases made by others.* -Allen

When asked about the learning methods in workplace, Ellis, an electrical engineer from shipbuilding industry with 3 year’s working experience, answered:

*At the beginning, my mentor told me what I need to pay attention to in the work process, and then I would explore it by myself. The guiding process impressed me deeply and made me grow faster.* -Ellis

**Discussion and conclusion**

So far, according to our participants, the current training in Chinese engineering education appeared to be insufficient in producing qualified engineers. In this context, sampled early-career engineers still needed to acquire or deepen the required KSAs through multiple venues, among which the most typical method is learning in the process of work completion.

Particularly, according to our participants, many industries in China have not established very mature training programs for new engineers yet. Therefore, the role of higher education plays in transiting engineering students from school to work is even more prominent. Therefore, there is an urgent need to explore workplace learning process not only to help engineering students get ready for work earlier but also to improve engineering education accordingly.

Based upon the preliminary work, future work will include two parts. First, the data collection will focus on engineers with bachelor's degree and engineers from extensive industries to enrich the conclusion. Next, more detailed analyses of qualitative data will be conducted using the framework of Cognitive Apprenticeship to provide practical suggestions for improving engineering education in China.

**References**


