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ENGINEERING STUDENTS REFLECT ON WORK-LIFE RELEVANT LEARNING

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ABSTRACT

As engineering education is a professional education, it should prepare students for working life. However, there are obvious limitations to the amount of content that is possible to cover and the authenticity of the learning environments. In this study, we investigate the students' awareness and perception of these limitations by answering the following two research questions: *What competencies do the students view as work-life relevant? How do students reflect on their opportunities to learn these competencies?* The context of the study is the five-year Master of Science in Engineering and Computer Science at KTH Royal Institute of Technology. Throughout the programme, the students attend a programme-integrated course with

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four reflection seminars including written assignments each year. In their fourth year they wrote reflections on their perceived work-life readiness and 38 of these reflections were analysed thematically in this study. We find that students expressed an elaborate view of what constitutes work-life relevant competencies. They readily identify learning experiences in the programme where they have developed such competencies, for instance through projects. They also show an understanding that there are limitations in the ability of the university environment to achieve fully authentic learning experiences. Many students see it as their own responsibility and necessity to complement their education with other opportunities for work-life relevant learning, such as hobby projects or internships. Others seem relaxed about any gap they may have in their work-life preparation and expect to learn on their first job.

1 INTRODUCTION

1.1 Preparing Engineering Students for Working Life

Engineering is a professional education and much work in the engineering education research community focuses on work-life relevant competencies (see for instance Buckley et al. 2022; Passow and Passow 2017; Trevelyan 2007, 2010; Jonassen et al. 2006) and, consequently, how education can better prepare students for working life (Crawley et al. 2014). In engineering education programmes, educators make efforts to address the knowledge and understandings, skills and abilities, and judgements and approaches that the graduates will need in working life. Even in many theoretical courses, the relevance of concepts is explained with reference to their practical use. Some parts of the education are organised to resemble professional practice, for instance project-based learning activities (Edström and Kolmos 2014). Still, there are limitations to the authenticity that can be created within the university environment, and within the scope, resources, and confines of an educational programme. Because of these limitations, it is necessary to question to what extent students are actually prepared for working life and studying the matter empirically can provide valuable feedback to educational programmes. This is often done from the perspective of the industry (Radermacher et al., 2014), but prior research has also been studied from a faculty perspective (Magnell and Kolmos 2017; Magnell, Geschwind and Kolmos 2017). Here, the issue is instead investigated from the perspective of students. This helps us better understand how they perceive their education which is important since it does not have to correspond with the perception of the faculty or the industry.

This study also serves as a starting point for a longitudinal research project investigating the students' progression from university into working life. In this project, a group of students will be followed from the later part of their education through their first year of working life. These students will be interviewed three times, once while finishing their master's thesis, and then twice during their first year of work (cf. Brunhaver et al. 2017). At this point, however, the students who participate in this study still have one year left before graduation. Guided by the following two research questions, we analyse written reflections addressing work-life relevant competencies.

- What competencies do the students view as work-life relevant?
- How do students reflect on their opportunities to learn these competencies?

However, it can be worth noting that as with all studies investigating perceptions, the students' view of work-life relevant competencies does not necessarily align with the actual relevant competencies.
In this paper, the term competency refers to *a combination of knowledge, skills and dispositions situated in a relevant context*. This definition corresponds to the competency model presented by Frezza et al. (2018).

2 METHODOLOGY

2.1 Context and Participants

The context of the study is the five-year Computer Science and Engineering programme at KTH Royal Institute of Technology. The first three years of the programme result in a bachelor's degree and the final two years in a master's degree in computer science. The programme contains courses that are mainly technical, as well as courses or learning activities that specifically support the students in developing professional skills such as communication and project work. One such course is the *Programme Integrated Course* (PIC) which aims to strengthen the programme coherence by allowing the students to reflect on the programme design and programme progression, and by addressing relevant topics such as study technique, ethics, ergonomics, procrastination, and mental health (Kann, 2019). The five-year programme contains two longitudinal PIC courses, one that spans over the first three years, and another over the final two.
In the PIC course, students are divided into groups, mixing students from all years enrolled in the course. For instance, in the second PIC, groups consist of 16-18 students from years four and five. Each group has a mentor from the computer science faculty who remains with the group throughout the course. Each year of the PIC consists of four seminars, addressing different topics. Before the seminar, the students read some preparatory material and write a reflection of 500-1000 words. They also read and give feedback on a selection of the other students' reflections.

2.2 Data collection

In this study, we analyse reflections written for a PIC seminar on the topic "*Future of Computer Science as a Profession*". The students were instructed to write about their own work-life readiness and the computer science skills and knowledge that they believe will be important in the future. The instruction was to take both the preparatory reading (Radermacher et al. 2014; Rainie and Anderson 2017; Loui and Miller 2008; Vinuesa et al. 2020) and their own experiences from the programme into consideration. While the reading probably helped the students deepen their reflections, it likely also influenced what they brought up as relevant. Our dataset in this study is limited to reflections submitted by the fourth-year students. Of the 111 students, 38 gave voluntary consent allowing their reflections to be used in this study. This selection could potentially affect the diversity and content of the reflections.

2.3 Thematic Analysis of the Student Reflections

To answer our research questions, we have taken an inductive data-driven approach following the framework for reflexive thematic analysis by Braun and Clark (2006; 2019). The analysis was done by iterating through the data several times. We started out by familiarise ourselves with the data, by reading through the reflections while making notes in the margins. We then coded the data, initially with pen and paper before going over the reflections again using the qualitative analysis software NVivo.

Through each iteration, some of the codes changed as we started to reach a better understanding of the material. This made it easier to group the codes into themes, which was also done iteratively as we finalised the coding and discussed the results. For example, the theme *theoretical subject competencies* consisted of codes such as *fundamental CS*, *theoretical knowledge*, *algorithms* and *mathematics*. All final themes for the two research questions are presented in the results section below.

RESULTS

In this section, we present the themes from the analyses of the student reflections for each of our two research questions. Excerpts from the interviews are used to further illustrate the themes and to protect the students' anonymity we have given them gender-neutral pseudonyms.

2.4 Work-Life Relevant Competencies

In the students' discussions of work-life relevant competencies, we generated the following six overarching themes: *practical subject competencies*, *theoretical subject competencies, engineering problem-solving*, *interpersonal and personal competencies*, *authentic project-related competencies* and *adaptability and self-regulated learning.* Each theme is presented in detail below. The subject competencies in this context are related to computer science, but their nature is not unique to CS.

Practical Subject Competencies
These competencies relate to the practical aspects of the engineering major, in this case, computer science. Students bring up specific topics, such as version control and unit testing, proficiency in different programming languages, interacting with databases, cloud computing, etc. One student discussing these types of competencies was Alex, who worried they might be lacking:

> "I unfortunately find that I personally will be lacking in several of these skills when graduating. This includes areas like testing, databases, debugging and configuration management." – Alex

Theoretical Subject Competencies
In this theme, students emphasise the theoretical areas of their education. This includes mathematics and theoretical aspects of computer science, such as algorithm design, theoretical knowledge about databases, different programming paradigms etc. Many students believed these competencies to be some of the most important ones to acquire at university since they are likely to stay current and act as a foundation when learning other competencies in the future. In Robin's words:

> "I think it is more important to have the theoretical background and fundamentals than the ability to use specific software." – Robin

Engineering Problem-Solving
Engineering problem-solving was frequently brought up as a foundational and future-proof engineering skill. The students also view it as a broad competence, closely connected with several of the other themes. One student motivating the importance of the theme was Kim:

> "Problem-solving is a very broad skill that will likely always be incredibly important, as almost all work as an engineer in any field will include problem-solving." - Kim

Interpersonal and Personal Competencies
This theme contains necessary competencies that students often categorise as "professional", "soft", or "non-technical". These include communication, collaboration,

creativity, critical thinking, ethical consideration, project and time management, intercultural competencies etc. Andrea motivates how proficiency in these competencies can aid work related to more technical themes:

> "Soft skills such as the ability to learn and adapt, communicate and work in a team are just as important now and will continue to be in the future. These skills ensure that the employees can apply their technical skills in a more effective and profitable way." – Andrea

Several students also provide concrete examples of when competencies from this theme are crucial. Jessie, for instance, commented:

> "And sometimes you don't even want to do what the client says they want, you need to understand why they want something, and perhaps offer a different and better solution." – Jessie

Authentic Project-Related Competencies

This is a broad theme covering the bigger picture of engineering. It focuses on how successful work in real, full-scale engineering projects requires multiple subject competencies used together. Students point out the big difference between their small homework problems or course projects and the projects that they will be part of when they enter the workforce. Such projects have more dependencies and the students might be given tasks that they rarely encountered during their education. Students brought up, for example, that they would need to be able to work with large code bases, follow industry standards, and handle production environments and deployment which they rarely, if ever, encounter during their degree.

> "I do think the ability to use different types of software and understand the big picture of things will be important." - Robin

Adaptability and Self-Regulated Learning

This theme captures competencies related to the concept of life-long learning which the students describe as crucial for work in technology since the industry changes quickly. This was one of the more frequently mentioned competencies. One of the students who stressed it was Noel:

> "One valuable skill is the ability to learn on your own, which makes it much easier to be a lifelong learner. This will make it possible to faster adapt to new advances in technology and in the field." – Noel

2.5 Opportunities to Learn the Work-Life Relevant Competencies

In this section, we present the four themes related to the second research question which addresses where and how the students think these competencies, which they had identified as work-life relevant, could and should be learned. The four themes were: *learning within the education programme*, *learning at work or internships during the education*, learning *through their own projects* and *learning at work after graduating*, and are described in detail below.

Learning within the Education Programme

The students naturally brought up their education programme as a place for developing several of the work-life relevant competencies. However, they also acknowledged challenges associated with teaching certain competencies in higher education due to both the lack of time and sufficiently authentic learning opportunities. This especially affected the *authentic project-related competencies* as well as some aspects of the *interpersonal and personal competencies* since there will be additional requirements in "real world" settings. Noel, for example, points out that although they practice aspects of communication, there are other aspects which are covered less in the programme:

> "Furthermore I probably lack skills working with customers, although I have done that in other jobs I have not done it in regards to software development. However, I feel like we practice communicating without using too much technical jargon etc." – Noel

The students also identified a number of practical subject competencies that they believed could have been taught more efficiently, for example by using more current software. However, they predominantly address the lack of progression that is caused by little focus on the necessary competencies in mandatory courses as well as the lack of assessment of these competencies. This requires the students to keep practising on their own or manage to choose the right elective courses (which can be difficult since they do not always know what is taught in the courses and what they need to focus on). Despite these issues, the students generally agreed that the role of the university was to provide a foundation consisting of *theoretical subject competencies*, *problem-solving* and *adaptability and self-regulated learning* which many claimed their education programme had succeeded with. In Charlie's words:

> "I understand that the courses mainly aim to build a foundation in the topics covered and I still think overall the learning outcomes are beneficial for the students taking the courses." – Charlie

Learning at Work or Internships during the Education

Since the lack of authentic learning opportunities was the main reason why the students believed they would not develop all necessary competencies to a satisfactory level, they naturally suggest the workplace as an additional learning environment. Several students mentioned that they either had software-related jobs on the side and/or that they had, or planned to, participate in summer internships in order to complement their degree. As mentioned by Elliot, internships can also help students experience what work-life entails:

> "Summer internships have enabled me to apply the skills I have learnt in university, deepening them while obtaining a better understanding of what is expected of me so that I can further prepare myself for life after graduation." – Elliot

Learning through their Own Projects

Another common strategy to lessen the competency gap is to pursue personal hobby projects or to participate in open-source projects. By creating their own projects, the students are also able to build portfolios which can be used to showcase both their technical skills and project planning. Additionally, open-source projects can be an opportunity to experience work in large codebases and to coordinate one's work with other developers. Noel is one of the students advocating for learning through projects and especially points out that this could be a way of learning different development tools which relate to both the *practical subject competencies* and *production competencies*.

> "I believe that my own skill gap could be fixed by […] creating projects on my own. One possibility could be to start contributing to open-source projects since that would force me to learn different development tools." – Noel

Learning at Work after Graduating

As mentioned above, many students seek opportunities for authentic learning opportunities by working on the side, participating in internships or learning on their own through hobby projects or open-source projects. However, we see that this is not applicable to everyone since they do not think that they have the time, energy or opportunity to participate in these activities. For some, their studies already take up all their time, while others have other jobs (not related to computer science) on the side and need the income. Some students express stress over this, while others were more relaxed. They were well aware that they would not be "fully trained" when

graduating and some even argued that it would take years of work experience until they reach sufficient proficiency in the practical competencies, as illustrated by Alex:

> "I think there are a lot of skills that can only be obtained through practical experience in the industry, skills that also do not simply arise five months into the work-life, but skills that will require perhaps a couple of years of professional experience." – Iliah

Some also point out that their prospective employers are aware of their need for additional training. Sasha explains:

> "There's also a reason why companies have "junior" and "senior" developers, it's okay to not know everything in the beginning and learn on the job. After a few years you will have learnt a lot and are hopefully ready to help the new graduates who are in the place you used to be." – Sasha

3 DISCUSSION AND CONCLUSION

Throughout the reflections, students show insight both into what competencies are relevant for working life and how these competencies can be acquired. They acknowledge that there are limitations to the authenticity that can be achieved within the learning environment at university and that this will affect their level of proficiency in some of the competencies when graduating. They also recognise that it would be impossible to learn everything that could be useful within the timeframe of their degree and that some skills and knowledge would be outdated when they graduate anyway due to the fast pace of the industry. Because of this, they primarily see the university as a place to build a theoretical foundation in their discipline and to learn how to obtain new knowledge and skills when needed which will be crucial in their future work-life. When students reflect on their acquisition of the necessary work-related competencies, they identify three responsible stakeholders: themselves, the university and their prospective employers. Between these three, we find that they express a balanced view of their shared responsibility. The university is responsible for providing high-quality education within its limitations, and although the students in this study were overall satisfied, many also point out that there is room for improvement. Since the university is not able to provide a fully authentic learning environment, the students argue that part of the responsibility has to be placed on their prospective employers to continue providing opportunities for learning and training when they start working. They also point out that there are a vast number of different branches and software within computer science which could be relevant when working at a company, making it impossible for them to be proficient in everything and able to execute all necessary work tasks. This further motivates why their employers will have to accommodate continued learning and training. Finally, many students recognise that they themselves have to take responsibility for their acquisition of some competencies to complement their university studies. They seem to accept their own responsibility and show awareness of a wide set of opportunities for learning.

They see opportunities for learning on their own, for instance through hobbies or open-source projects, or through work or internships in parallel with their degree. This can however be difficult for some students, either due to economic reasons or time and energy limitations. Some state that they are unable to do anything extra beyond their studies.

As mentioned previously, this study does have limitations. The data consists of student reflections which were guided and influenced by preparatory reading. However, the students related the reading to their own experiences in the programme and many students also disagreed with the reading. Further, the

students knew that their reflections would be read and commented on by their peers and mentor, hence it is possible that they may have underplayed their insecurities. The voluntary selection of students may have additionally increased the bias in favour of students who were proud of their assignments and felt that they displayed maturity. In the future longitudinal part of the study when we interview a sample of these students, it is possible that we may get to hear some more vulnerable views.

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