When industry meets Education 4.0: What do Computer Science companies need from Higher Education?

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ABSTRACT

Education 4.0 emphasises the development of skills and competences necessary in a modern workplace. In this paper, we explored what these Education 4.0 skills look like through exploring the opinions of industry professionals in the Computer Science (CS) sector. A series of focus groups involving CS companies from across Europe were used to identify the skills required and the current gaps in training for CS graduates. The two main gaps identified by companies were graduates' lack of soft skills and challenges to applying theoretical knowledge to different practical contexts. Strengths identified included good knowledge of programming and interacting with clients and customers on a technical level. Amongst the suggested ways for addressing these gaps were a close collaboration between industry and academia through company placements and opportunities for project-based learning in higher education.

CCS CONCEPTS

• **Social and professional topics**→ Professional topics; Computing profession; Computing occupations.

KEYWORDS

Engineering education, Education 4.0, graduate students, skills, computer science, employers, companies

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1 BACKGROUND

Education 4.0 employs an approach to learning and teaching that emphasises the development of skills and competences necessary in a modern workplace using up-to-date technology. The skills and competences developed may relate directly to technology, or they may relate to softer skills. In order to understand the concept of Education 4.0, we need to understand the Industrial Revolution (IR) 4.0 [1]. During the third IR, electronics and information technology (IT) were used to automate production [2]. The fourth IR is beyond an enhancement of the third IR, in which the advancement of new technologies blurs the lines between the physical, digital and biological worlds. Education 4.0 is a response to the needs of IR 4.0 where human and technology are aligned to enable new possibilities. As Fisk [3] argued, the new vision of learning promotes students to learn not only skills and knowledge that are needed but also to identify the source to learn these skills and knowledge. Therefore, learning is built around students as to where and how to learn, and tracking of their performance is done through data-based customisation [4]. Peers become very important through learning together and from each other, while the educators assume the role of facilitators in learning. The trends of Education 4.0 shift the major learning responsibilities from educators to students when the demands for the acquisition of professional skills are particularly stringent in engineering related disciplines [1, 2, 5].

Driven by IR 4.0 and digital technology, jobs are becoming more flexible and complex [4]. People's capacities to be entrepreneurial

[6], manage complex information [7], think autonomously and creatively [8], use resources, including digital ones, smartly, communicate effectively [9] and be resilient [10] are more crucial than ever. Europe also needs more high achievers who can develop cutting-edge technologies and solutions on which our future prosperity depends [11]. Without higher education institutions (HEIs) and systems that are effective in education, and research and innovation connected to society, Europe cannot respond to these challenges. Previous research has identified the need to address (soft) skills for Computer Science (CS) graduate students including critical thinking, leadership, teamwork, and communication [12, 13].For example, Garousi et al. [13] indicated that "it is widely discussed in the community that hard (technical) skills alone do not make a great software engineer . . . and soft skills are equally important (if not more)". In this respect, the literature indicates serious gaps in the provision of these skills within university-level courses [14]. Previous research evidences a mismatch between skills developed during university CS studies and the skills needed at the workplace [15]. Thus, it is necessary to investigate how these skills should be taught to meet companies' expectations.

While CS education has traditionally focussed on state-of-the-art knowledge transfer, skills, and competences, in the last ten years a range of more active learning methods have been introduced to encourage CS graduates to develop and nurture some of these softer skills. A recurring theme seems to be a shift from teachers as being a knowledge transmitter to teachers as facilitators, moderators or consultants of learning [16]. Teachers could achieve that by being flexible (adapt to change) [17], supportive, help students to develop ownership of learning [18], foster an environment where students take risks and share what they do not know about, and where failure is acceptable [16]. This role was often discussed within a flipped classroom implementation [19] that could give control to students to study the teaching material at their own pace and contact the teacher to solve problems and discuss their learning. In such conditions, a teacher is monitoring a student's progress and facilitates understanding through discussions [20]. Indeed, an increasing number of CS teachers have started to implement project-based learning and hands-on experiences in their classroom [21].

This research is part of a wider project, Teach4Edu4, which aims to enable the creation of an Education 4.0 environment that supports the implementation of new learning and teaching approaches in CS and related disciplines. To create that environment and incorporate innovative practices within CS teaching, we first need to understand what industry, in particular current CS companies need and desire from CS graduates, and whether (or not) the current provision by HEIs meets their needs. For that purpose, a set of focus groups with several European companies was conducted to understand their experiences while contracting and working with CS graduates. The objective of the focus groups is to better understand the knowledge and skills graduates have and what might be missing, and collecting inputs from industry on how to effectively integrate them within innovative teaching methods.

2 METHODOLOGY

Focus groups were selected as the research method because they allow collecting data through interactive and directed discussions by the researchers. It is a form of qualitative research consisting of a group conversation in which prompts are given to elicit sharing data about perceptions, opinions, beliefs, and attitudes from compelling and authoritative respondents [22]. Participants were asked to select a date and time that suited their availability and the focus groups were subsequently organised at a mutually convenient time. Questions were asked in an interactive group setting where participants were free to talk with other group members. A semi-structured interview guide was constructed, and the questions were shared with participants using PowerPoint slides. Advantages in focus groups include the diversity of voices and opinions included in those authoritative responses, while disadvantages include the influence of the majority and quiet voices not having an opportunity to talk.

The recruitment was via an invitation email to respective companies who have partnered with the Teach4Edu4 project. Participants were approached from a closed list provided by six CS HEIs involved in Teach4Edu4; these companies have experience collaborating for research purposes with the HEIs. The recruitment process and seven focus groups were run from January until April 2021. All focus groups were conducted online and recorded using Microsoft Teams[1]. The focus groups included eleven participants as disclosed in Table 1 from five European countries. The sample was self-selected and included a range of different types of companies: foundations, private, public entities, and large international companies.

Research through focus groups had the approval of The Open University (OU) Human Research Ethics Committee and all participants signed a consent form to participate. The language of focus groups was English, to facilitate a mixture of opinions from different countries to emerge. There were several researchers from two HEIs who moderated the focus groups (i.e., The OU and Polytechnic University of Catalonia (UPC)). The semi-structured focus groups were based on several key themes which included desirable skills, competencies, knowledge, and views of CS graduates, and lasted between 45-60 minutes.

In Table 2 the respective structure and areas to cover of the focus groups are detailed. Section 1 was designed as an icebreaker, sections 2, 3 and 4 discussed the CS graduates' knowledge, skills and competences when joining the company. Section 5 used a visual mediating artefact from Garousi et al. [13] to allow discussion about the importance of skills and missing gaps identified. As CS skills can be particularly sensitive topics, this visual mediating artefact was introduced to encourage in-depth discussion and reflection. This method has been highlighted in previous research [23] as a powerful way to elicit complex thoughts and feelings in an environment that is perceived as 'safe' by the participant [24].

Full transcriptions of the focus groups were produced by the tool Otter[2] automatically and then reviewed manually for consistency by members of UPC. Once edited for accuracy, the transcriptions were added to Nvivo[3] software. Thematic analysis as described in the next section was selected as the analysis method [25]. The

[1] Microsoft Teams, https://www.microsoft.com/en-ww/microsoft-teams/group-chat-software
[2] Otter, https://otter.ai/
[3] NVIVO, https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Table 1: Focus groups sample

Country	Type	Size	Participants
Croatia	Technology park	Medium	2
Croatia	Private Company	Small	1
Croatia	Private Company	Small	1
Slovakia	Private Company	Medium	2
Slovakia	Private Company	Large	1
Slovakia	Private Company	Large	1
The UK	Private Foundation	Medium	1
Italy	University Company	Small	1
Spain	Public Foundation	Small	1

Table 2: Structure of the focus groups

	Section	Areas and questions to cover
1	Tell us about your company, and what your specific role is (10 min) (ice breaker activity)	• How large is your company? • How many CS graduates have you recruited in the last 2 years? • What is your definition of CS? (What is and what is not)
2	CS graduates' knowledge, skills and competences when starting at your company (10 min)	• What are the expectations you have when recruiting new CS graduates? • What key knowledge, skills, and competences the company would benefit from that CS graduates are missing or bringing? • What are the key problems CS graduates face when integrating into the company? • To summarise: What are your overall impressions of these CS graduates?
3	How knowledge, skills and competences are affecting the company day to day work (10 min)	• What is the training they receive when joining the company? • What are the roles and responsibilities they take from the starting? • How do they interact with clients and customers?
4	How knowledge, skills and competences could be acquired before and integrated within appropriate teaching methods (10 min)	• How the knowledge, skills and competences could be acquired before? • Which innovative methods could be included?
5	In the following visualisation of a review of key skills required in software engineering (10 min)	• Do you agree with this visualisation, or do you think some key skills are missing?

stages of analysis involved each transcript being read by a member of The OU and initially coded.

Once all the transcripts were coded, they were reviewed by the authors for commonalities and re-occurring themes using both references, frequencies and reviewing the content that was coded. A draft set of themes were then created and shared with the broader team to discuss and review. These themes were then compared back with the data to clarify their appropriate interpretation of the data. The outcomes of this data analysis process are shared in the results section below.

3 RESULTS

In total four main themes were constructed from the conversations with the eleven participants, namely 1) Strengths CS graduates bring

from university; 2) Gaps in skills or knowledge from university; 3) Innovative ways of addressing these gaps; 4) Areas that companies work with their graduates to develop.

3.1 Strengths CS graduates bring from university

The skills that CS graduates would bring from university included in-depth and up-to-date programming and/or technical knowledge. This might be knowledge of new software or hardware that other employees in the company might not have. This was seen to address a skills gap: "Graduates are typically very well prepared regarding the usage of different software technologies. They are skilled, they know a lot of things regarding how to develop software" (R11, Slovakia, Private Company, Big).

Other areas that were seen as strengths were the ability to interact with clients and customers on a technical level: "In a technical level, they can interact totally with the clients and customers" (R2, Croatia, Private Company, Small).

3.2 Gaps in skills or knowledge from university

Participants discussed how CS graduates tended to arrive at their company with a sound knowledge of technical skills in specific pieces of technology, but often lacked what was described as 'softer skills' (i.e., communication skills, organisation, teamwork). For example, a participant discussed this gap in certain types of skills. "From my perspective, our students have good conceptual skills and good enough technical skills, but sometimes not yet enough social and communication skills" (R9, Italy, University Company, Small). This area was also discussed throughout the other focus groups:

> "For me, communication is an important thing, especially when you have to communicate it to people who the only thing, they know about computers is that they have one button to start them up. Communication skills are important. It's a thing that usually it's totally forgotten." (R2, Croatia, Private Company, Small)

Participants often talked about generic training that they offered new graduates, such as getting to know the culture of the business, IT processes, etc., yet not more individualised and personalised professional development. For example, the importance of getting to know the culture of the company was discussed:

> "Getting the feel of the company's culture. This is important because you can have someone with great technical skills, but whose values or work approach to work is not in line with the company's culture. That can be a problem. Internalising the values of the company is also a really important part when joining a team." (R4, Croatia, Technology park, Medium)

Other gaps included asking critical questions, challenging others, decision making or knowing when to ask for help. Graduates were perceived to struggle to apply their technical skills from what they had been taught at university to different scenarios or projects. Therefore, the graduates' abilities to move from applying their technology skills on a theoretical level into a practical application was seen as a gap by several interviewees. In particular, it was seen that perhaps graduates were too focused on learning particular pieces of technology or software rather than having a broader knowledge in terms of applying different technologies to projects or contexts:

> "I think this is the biggest gap in the current environment, like the students, are mostly really good prepared in the 'how'. They know how to build something. They know the 'when', they know the 'how' and they know the 'who', but they don't know the 'why'. Understanding the 'why' and asking the right questions. To bring the solution in terms of time use scalability is something that that I would appreciate it was more of a focus." (R6, UK, Private Foundation, Medium)

Other gaps that were discussed included lacking passion, appropriate attitude or motivation for their new roles and the ability to experiment with the learning that they had gained from university: "What we see is that many of them are simply not motivated or willing to step out of those boundaries. They do the minimum they require for gaining a degree" (R5, Croatia, Private Company, Small). That being said, this was not the case for all the focus groups. Indeed, the inverse was discussed in terms of graduates bringing drive and motivation into the company:

> "Typically graduates are young, they want to show to the world that they are skilled, and they are ready to go to achieve something, and they can, I would say, change the flow in the company. They are bringing a lot of drive into the company" (R10, Slovakia, Private Company, Big).

3.3 Innovative ways of addressing these gaps

Several ideas were put forward from participants in terms of how the gaps mentioned above could be addressed. These included allowing graduates to undertake work placements during their studies in different companies to get some experience of how to apply their skills in the workplace. Additionally, an increase in project-based learning opportunities in their university studies would allow the graduates to apply their theoretical knowledge and use problem-solving to adapt and apply their skills. Finally, getting colleagues from the companies to deliver or practically apply certain bits of content within the university course was suggested as a way in which the theory-practice gap could be addressed:

> "That's why I think it's fundamental to have seminars from a company, I have seminars from companies time to time (. . .). These are things that indeed, we tell them in our courses. But I believe that when the same message comes from the company, it strongly reinforces the message is coming from the academia, because otherwise academia can be seen, like theoretical things that are not used in the company." (R9, Italy, University Company, Small)

Therefore, bringing experiences from the working environment into the university context would help graduates to apply some of their theoretical knowledge to practice.

Table 3: Key findings from the focus groups

	Theme	Key findings
1	Strengths that CS graduates bring from university	1.Programming and in-depth technical knowledge 2. Skills of new software that others in the company might not have 3.Interacting on a technical level with clients and customers
2	Gaps CS graduates have when coming from university	1.Soft skills 2. Move from the theoretical level into the practical application 3.Too focused on particular technologies 4.Challenge and ask critical questions – know when to ask for help 5.Lacking the passion, attitude or motivation
3	Innovative ways of addressing these gaps	1.Work placements in companies 2. Project-based learning that involves problem solving 3. Getting people from the company to deliver certain bits of content
4	Areas that companies work with their graduates to develop	1.Developing confidence in their knowledge and abilities 2.Mentorship support so that they can learn from other colleagues 3.Knowledge, skills and competences of the IT processes 4. The company culture and ways of working

3.4 Areas that companies work with their graduates to develop

The areas mentioned as those in which companies would work with their graduates to develop within the workplace setting would be developing their confidence in their knowledge and abilities. This would include independent learning and thinking about how they could put new ideas forward:

> "[Graduates] to understand that they can impact the company, they can impact the actual project they work on, no matter how much experience they have, because they might have different views, they might have different opinions, which might not be right, but it could be right (. . .). They have a fresh view on things, which I think should be encouraged." (R3, Croatia, Technology park, Medium)

Mentorship support from other colleagues was also mentioned as a means in which both graduates and employees could learn from one another and provide a supportive development environment. "The kind of training they receive when joining the company, one module is also the mentoring, every new guy gets a mentor" (R11, Slovakia, Private Company, Big). More standardised forms of development for CS graduates would also include the knowledge of IT processes that the company uses and inductions into the company culture and ways of working.

4 DISCUSSION

This exploratory research has helped to identify skills required and the current gaps in training for graduates joining Computer Science (CS) companies. As disclosed in Table 3 the eleven participants interviewed in the focus groups saw as one of the strengths that graduates supply to the company knowledge of programming and interacting with clients and customers on a technical level. At the same time, graduates often lacked soft skills such as communication and teamwork when joining their company directly from university. Similarly, CS graduates often struggle to apply their detailed theoretical knowledge to different practical contexts. These aspects align with previous research stressing the need to address soft skills [13] and apply critical thinking to non-theoretical environments (i.e., real-life experiences) [12].

There were various suggestions in ways that these gaps could be addressed, which include a closer collaboration between industry and academia supported by company placements, guest speakers at universities, and project-based learning experiences. As acknowledged current experiences are moving towards facilitating engaging learning practices [16], implementing project-based learning and hands-on experiences [21]. Areas that CS companies feel that they could work with their graduates to develop include confidence in their abilities and mentoring support from another colleagues. Learning mechanisms that are viewed as important by partners include being able to learn on the job, independent learning, asking critical questions, and take on board feedback. Current research

is exploring that flexibility [17], supportiveness [18] and adapting critical thinking through discussions [20].

5 CONCLUSIONS

We acknowledge the limitations of a reduced sample of eleven focus group participants from four European countries to capture the full depth and diversity of graduate experiences in companies. While this study indicates similar gaps as previously reported in the literature, the study presented facilitates wider research within the project including an extensive catalogue of new forms of teaching, learning and assessment in CS in Education 4.0 and related teachers' skills and competences. The introduction of new teaching methods presupposes important challenges and changes in conceptualising the role of university lecturers, their educational profiles, and the contextual preparation of teaching material. Likewise, how CS competencies are developed and the design of the assessment methods to evaluate graduates' capabilities should be carefully crafted under coherent guiding principles throughout the entire curricula. Thus, not only academic content but also the teaching methods should be debated [5]. Accordingly, there is a need for further study addressing this topic, as the quality and usefulness of the educational practice is key for 'producing' highly skilled, competent, and successful CS graduates.

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