Barr, M. and Nabi, S. W. (2022) The Development of Students' Employability Skills on a Work-Based Software Engineering Degree Programme. In: 2022 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden, 8-11 October 2022, ISBN 9781665462440

(doi: [10.1109/FIE56618.2022.9962611](https://doi.org/10.1109/FIE56618.2022.9962611))

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Deposited on: 15 June 2022

The Development of Students' Employability Skills on a Work-Based Software Engineering Degree Programme

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Abstract—Work-based degree programmes are seen as a means of addressing the reported lack of employability skills in Computing Science (CS) graduates. In the UK, work-based CS degree programmes – or *apprenticeships* – were established to close this skills gap. In Scotland, a national 'meta-skills' framework has been developed, comprising twelve employability skills (for example, 'Adapting', 'Communicating') grouped under three headings (Self management, Social intelligence, and Innovation). This paper explores how a cohort of Software Engineering apprentices (N = 30) developed these meta-skills during their time in the workplace, across the first year of their programme. Apprentices were asked to report on the meta-skills they felt they had developed most in the workplace, with reference to the published framework. The most prevalent skill said to have been developed in the workplace was 'Communicating', followed by 'Focusing' and 'Adapting', both of which fall under the heading of 'Self management'. The data presented here illustrate how students developed their meta-skills while working as apprentice Software Engineers. Meanwhile, a significant emergent theme that appears to underpin the development of many of these meta-skills is *confidence*. This work provides evidence of how a Software Engineering apprenticeship may develop specific employability skills. It supports assumptions about the benefits of work-based learning in computing education, and suggests that apprenticeships may help address the employability skills deficit in CS graduates.

Index Terms—Higher education, Professional skills, Employability, Communication skills, Workplace

I. INTRODUCTION

Work-based degree programmes — or *apprenticeships* - – are seen as a means of addressing the reported lack of employability skills in Computing Science (CS) graduates [1]. Indeed, in the UK, the government's Shadbolt review found that CS graduates were notably less employable than students graduating from other STEM disciplines. The review recommended an increased emphasis on work experience to improve graduates' "softer and work readiness skills" [2], and work-based CS degree programmes were established to close this skills gap [3], [4]. In Scotland, where the work described here was carried out, a 'meta-skills' framework has been developed by the national body, Skills Development Scotland (SDS). SDS are also the body responsible for overseeing the development and delivery of apprenticeships in Scotland.

The meta-skills framework draws on international work by the Organisation for Economic Co-operation and Development (OECD), the World Economic Forum, and PwC, and comprises twelve meta-skills (such as 'Adapting', 'Communicating', and 'Collaborating') grouped under three headings ('Self management', 'Social intelligence', and 'Innovation') [5]. Such meta-skills are also known as employability skills, professional skills, or, in higher education, graduate attributes [6]. Here, we explore how a cohort of Software Engineering apprentices (N = 30) developed these meta-skills during their time in the workplace, across the first year of their programme. As is typical of a work-based degree, the students here spend a portion of the year at university, but the majority of their time is spent with their employers, working as apprentice Software Engineers. The design and development of the programme is described in more detail by Barr & Parkinson [7].

II. METHODS

The goal of this research was to determine how apprentices develop their employability skills in the workplace, using the SDS meta-skills framework as the theoretical basis for the work. Apprentices were asked to produce a 1500-word report on the meta-skills they felt they had developed most in the workplace, with reference to the published framework. The question asked of apprentices was "How have you developed these meta-skills in the workplace?", with a link provided to a one-page summary of the meta-skills framework. This was an assessed piece of work, resulting in a 100% response rate. Reports were analysed using a straightforward deductive approach, with the meta-skills framework providing a set of *a priori* themes. A further round of inductive thematic analysis was conducted to capture any emergent themes. Hybrid approaches to thematic analysis, which combine "top-down" deductive analysis and "bottom-up" inductive analysis [8], [9], are often appropriate in educational research [10], [11]. In line with Braun & Clarke's approach to thematic analysis [12], our process involved the authors familiarising themselves with the

data, noting any interesting codes, and grouping these into themes. Following a discussion of this initial coding with the second author, it was agreed that *confidence* was the only significant additional theme to have been identified in the data, over-and-above the *a priori* themes relating to specific meta-skills. Ethical approval for this work was obtained from the College Ethics Committee.

III. RESULTS AND DISCUSSION

Each apprentice identified an average of three meta-skills. The most prevalent skill said to have been developed in the workplace was 'Communicating', with 22 of 30 apprentices indicating that their ability to communicate had been enhanced. The next most prevalent skills were 'Focusing' (N = 15) and 'Adapting' (N = 14), both of which fall under the heading of 'Self management'. The remaining nine meta-skills were each identified by between one and eight students, with the 'Feeling' meta-skill being the least prevalent (N = 1). Here, the reported means by which the three most prevalent meta-skills were developed are considered in detail. This is followed by a summary of the data relating to the development of the remaining meta-skills, and a discussion of the role of confidence in meta-skills development.

A. Communicating

> My interpersonal skills have improved as a direct result of making the effort to communicate with my colleagues. I now have a clearer understanding of the value of the relationships I make in work. – Liam

Clearly, communication plays a vital role in any workplace, and the apprentices here identify many means by which their communication skills are exercised in their day-to-day roles. For example:

> Communicating is a meta skill that I have developed significantly from working across two projects this year. One has involved moving the project to a new server so I have had to speak to our infrastructure team in order to decide on where it could go and how we could action this. In my other project, I have spoken to our security team so that we could get temporary logins setup [for users]. This was an interesting thing to figure out; it took quite a bit of back and forward and involving many people to find [that] the format decided on for the usernames was causing problems in an old legacy system. – Noah

This same student also suggests that their experience of supporting the software they've been developing has enhanced their ability to communicate with external stakeholders from different teams:

> I also began taking on support this year. This allowed me to deal with [a range of stakeholders], and develop professional mannerisms for responding to tickets. This also, surprisingly to me helped with my intra-team communication skills, as [...] a lot of unrelated support tickets got filed to us, so I had to work out what teams dealt with these issues. – Noah

Communicating with colleagues was frequently cited as a means by which this meta-skill was developed. For example:

> Before entering this GA program, I would consider my communication to be already strong, but the last two years have allowed me to develop this skill in a professional capacity, regarding emailing colleagues, communicating with interfacing teams, or being a contributing voice in team meetings. The workplace has afforded me to exercise my communication skills and enlighten me on the best approaches of communication with various people. – Elijah

As noted above, communication is reported to have been developed as a result of working as part of a team, as well as working across teams. Another example:

> Since I started my time in the workplace, I have developed my communication skills and have become well versed in being able to express my ideas fluently. I regularly work with others in the completion of a task, so my skills in explaining the processes and changes involved have grown to accommodate this requirement of explaining the thought process behind a decision. – Leo

And, related to working within a team, many of the apprentices here referred to taking part in the various meetings associated with modern software engineering practice, such as stand-ups and retrospectives:

> I took part in my team's daily stand ups where we would discuss what we had done over the past day, what we were going to be doing for the next day and if we had any issues that had arisen. I got used to talking to my team as a whole and being able to communicate any troubles I had or if everything was on track. This helped me to build my communication skills as I had to make sure that my team understood precisely what I was doing and what I was going to do. – Lucas

> After partaking in a handful of retrospective meetings, I have remarkably improved my ability to collect opinions and ideas I have formed over a long period of time, transform them into well justified arguments and present them to my colleagues as constructive criticism, whilst also enhancing my capacity to consider others' views on the subject. – Ella

Another common software engineering practice is that of code review, wherein an engineer's code is presented and reviewed by their peers. Code reviews offer an additional opportunity to develop communication skills, as this apprentice observed:

> Code reviews have been a specific area where I have not only noticed an improvement in my communication skills, but also noticed the benefits it brings. At first, I struggled to explain the code I had written. Unsure of what I needed to say, my code reviews often fell into the trap of being an incoherent

reading of the lines of code which didn't actually express what the code was doing. [Now] I focus on explaining the code at a higher level and how the code achieves an outcome and the reasoning behind this, rather than what lines make it up. – Isaac

One apprentice described the kick-off and handover meetings run by developers within their organisation, where they must communicate their understanding of the story being worked upon. This ensures all of the development, quality assurance, and business analysis stakeholders share an understanding of the functionality to be implemented:

Repeatedly running [kick-off] sessions, as well as running stand-ups, attending team meetings and retros and having to communicate constantly as the live support and development pair has, for me, meant that communicating has been my most improved meta skill during this apprenticeship. – Amira

Given that teams may comprise a diverse set of stakeholders, with varying degrees of technical knowledge it is, perhaps, not surprising that this has exercised apprentices' communication skills, too:

[Another] skill I developed was presenting complex information to my manager or to non-technical staff. [...] I have found presenting technical information very challenging as it is often difficult to explain concepts, and a lot may need to be explained in a short period of time. However, I have found it useful to use analogies to help my audience compare the concepts to something that is more familiar to them. I have developed this skill continually in weekly catch-up meetings and in more formal project meetings. – Ahmed

Of course, workplace communication is not confined to the spoken word: written communication also plays an important role. For example, in the writing of documentation – a task that many traditional undergraduate students may deem superfluous, before they enter the workplace:

It was my responsibility to document this new [Java] framework in such a manner that members of the team could easily grasp the approach. This experience greatly improved my communication in written format due to the fact that I had discourse with many different members of the team regarding what to include and exclude from this documentation, while also expanding my use of technical terminology. – Alex

As noted by one apprentice, the ability to write effective emails is another important form of written communication in the workplace: "I now realise how important it is to get your point across in a couple of sentences, set deadlines and also how to be formal." (Finn). In fact, many of the apprentices here reported that the quality of their written communication had improved as a result of being required to write effective emails:

Through writing emails, I believe that my communication skills have improved through an increase in vocabulary and grammar skills by trying to make my emails look more professional. My skills have also increased from re-reading emails to check for mistakes which has made a great change in my email writing as there is a lot less mistakes in my emails now and I can learn from my mistakes when I find them. – Lucas

It is not just speaking communication that I feel I have improved since starting my role, I also feel like my email writing ability has vastly improved, as I am doing it on a near-daily basis. As I come from a purely academic background, with little professional experience in an office, I hadn't had much exposure to email writing when I started my apprenticeship. – Jamie

Furthermore, in both written and verbal communication, there is skill associated with asking questions in the most effective manner, as observed by this apprentice:

I often would find when I asked someone a question, the reply I got wasn't what I was actually looking for and I would need to reword my question to get the answer I was. [...] Now when I ask questions within the workplace, they are concise in expressing the information I am aiming to get which usually leads to a better and more helpful answer. – Isaac

Finally, an insightful observation about how the experience of an apprentice differs from that of a traditional undergraduate student, in terms of the expectations around communication:

As a result of this experience I have observed that there is a common and incorrect assumption [...] that communication is unidirectional when in fact it should be bidirectional, meaning that information should not only flow top-down to colleagues but also bottom-up to management. I think that this is natural considering the typical asymmetry of communication in a student's prior experiences before beginning a professional career e.g. being lectured or presented to [...] I believe that this is the most important lesson I have learned with regards to communication and I understand how it can be easily overlooked. – Muhammad

The work-based experience is fundamentally different from being at university. As documented here, apprentices learn to communicate in a professional environment from the outset of their degree programme, developing written and verbal communication skills as required.

B. Focusing

I believe that operating over three separate project groups is imperative for allowing me to develop my ability to focus on my role." – Han

The SDS framework describes this meta-skill in terms of the ability to focus on the present and avoid distractions, "to

filter out non-essential information and focus on the essential problem at hand" [5]. Several apprentices refer to having to investigate new technologies, to find the information they need to solve the problem they're working on. For example:

> My experience of investigating new technologies or solutions and managing my workload between projects has given me the chance to hone my ability to focus. Having to research technologies and their intricacies requires a considerable amount of focus and attention to be able to apply them in a useful manner. – Leo

The framework suggests that being able to maintain focus in a complex, information-heavy environment is key to being productive. This is especially the case when searching for the information required to complete a task uncovers many different possible solutions – some of which are potentially unhelpful:

> Another aspect of focusing, is focusing your effort on the correct things. I'm sure everyone can relate to some degree of spending an excess of time on something for it just to have been a waste. One thing I have found to minimize this is to have the specification of what I am trying to do visible and to constantly remind myself of it to ensure that I stay on track and don't end up wasting effort doing something wrong and or unnecessary. – Isaac

The students here are aware that being enrolled in an apprenticeship programme means they must juggle the demands placed on them by both their employer and their university, which requires additional focus:

> Focusing is a skill which I believe I have improved, mainly due to [the] nature of how the course is run. You must be able to effectively split and manage both the university and work side of the programme. It can be distracting as we have deadlines for both. – Muhammad

The importance of taking breaks in order to maintain the ability to focus was identified by many apprentices. This is a useful realisation for any student or employee, but it is perhaps all the more important when an apprentice is balancing both work and study – and the associated deadlines. For example:

> I found myself not taking time off, working, studying, and doing University assessments, without taking any breaks. What this last year has taught me, is always plan more than two days off, which allows you to recharge and gain focus on what is going on. – James

> Another way that I find useful in helping me stay focused is to take breaks. Taking small regular breaks throughout the day has really helped me stay focused on what I am working on. These are all very crucial as it is very important to stay focused when working on a task, especially if they are tight deadlines to meet. – Luca

Learning to block out time is discussed in more detail below, but here one apprentice notes the importance of allocating time to relaxation:

> In my experience the time taken away from my work (where I blocked out 'cool down' periods to relax between more intensive sessions) were equally as important as the work time block. Allocating specific time to read a novel or watch a [TV] program stopped me from seeking out these types of distractions while I was in the middle of working. – Liam

Many apprentices here describe the techniques they have discovered or developed in the workplace to aid with their focus. These techniques may be as simple as "taking five minutes after every meeting to think about it and write up a list of notes" (Luca), but they can also incorporate more holistic approaches to time management. Planning ahead and prioritising workload is a common theme, even if this involves little more than maintaining a list of tasks:

> When I did find myself losing focus, I would ensure to make a priority list, either on my phone or laptop, which ever was being used at the time, and this allowed me to take a lot of pressure away from tasks that did not need done there and then. This allowed me to regain my focus and take on the tasks that had to be done. – James

Others, however, have developed more sophisticated approaches to planning their work:

> I have been able to [manage and prioritise workload] by developing a system whereby I try to take some time every fortnight to plan the two weeks ahead. By looking to see what projects I need to work on, as well as any meetings, events and training I need to attend or complete, I can get a good overview of my availability over the coming weeks, and by prioritising these and blocking off time to complete them in my calendar, I can ensure I always have time allocated to give each work item the due care and attention that it requires. – Theo

Here, the apprentice refers to "blocking off time", which is something that many apprentices reported having learned to do in the workplace. For example:

> For me, blocking out time to do specific tasks was difficult at first. I often got distracted by other subjects or the research I was doing on the technology I was trying to learn would lead me off on tangents. To improve the quality of my focus, I started with smaller blocks of time to make it easier on myself and then increased the lengths of the time blocks incrementally as I progressed. – Liam

Another apprentice refers to this approach as 'time boxing', which has been something of a revelation for them:

> I began to look into time management methods and came across a technique called Time Boxing. Having

read about this way of working, I now realise where I was going wrong previously. I was not considering the processes involved in the tasks that I chose, as well any blockers that may arise as part of that process (for example awaiting approval or response from another team). Thanks to this technique, I have significantly improved my understanding of time management and my meta-skills in focus and initiative. – Amelia

Still another apprentice describes how they have also learned to block out their time to improve focus, in this case referring to the Pomodoro technique:

I would have 3 pieces of work and I would complete the first one that came in rather than equally spend time on each. This was no use as timelines for each of the tasks were very different. I took it upon myself to ask my line manger if there were more effective techniques, and he mentioned the Pomodoro technique which is the art of setting timers at 25 minutes, have 5 minute breaks, then work on something else for 25 minutes, then another 5 minute break. I trialled this for a week and the results were great. I felt myself more engaged with my work and less frustrated. – Ethan

Apprentices have also learned how to improve their focus by using the "array of tools and good practices" available to them in the workplace:

Managing my diary during work time has been done using my Outlook calendar, where I would book appointments in my schedule for myself and my manager to see. Doing this would also reflect on my status in the communications channels, so if I was working on a coding task that would require focus, setting the appointment up in my calendar would show me as "busy" in Skype and other comms. – Elijah

Again, this is a point of difference between the work-based experience and a traditional university environment, where students typically are not exposed to shared calendars and other workplace practices that might improve their ability to focus.

C. Adapting

What I have learned for developing [the] adapting skill is, always be enthusiastic about new things, be open and resilient, and learn more about it before putting it into practice. – Ava

The comment above encapsulates how the 'Adapting' meta-skill is presented in the framework, with its emphasis on resilience, or the "ability to respond positively and constructively to constantly evolving challenges and complexity" [5]. However, perhaps the most obvious opportunity to develop adaptability here is in dealing with the wide range of technologies and practices used by apprentices' employers:

My time in the workplace has given me opportunities to work on my adaptability, as I have been involved in many different projects, often requiring their own processes and some even using completely different systems and programming languages. This has meant that I have had to investigate and acquaint myself with these new systems in a timely manner so as to work on the task itself. Not only have I had the chance to work with many different projects, but I have also worked in multiple teams, giving me the experience of having to adapt to an entirely different approach to the development process and team practices. – Leo

The language we used in school was Visual Basic and that was all I had ever known. On my project we use a number of different languages but mainly C# and Vue.js which I have become very familiar with. At the beginning, I was using my knowledge of Visual Basic and trying to apply the same concepts to C#. However some can be vastly different. Although after time I became adjusted to the new conditions. This came from practice. Repeatedly practicing. – Zara

The framework also suggests that the 'Adapting' meta-skill involves "flexibility when handling the unexpected, adapting to circumstances as they arise" [5]. Given that this cohort of apprentices enrolled on the programme around six months before the COVID-19 pandemic resulted in unprecedented changes to how we work and study, it is no surprise that the data here include references to adapting to the 'new normal':

The ability to adapt has been paramount to this graduate apprenticeship program. From adapting to the new online format for university, new courses, subjects, and ways of thinking - to adapting to the changes in working environment and to a new way of life one could say; all have been challenging in their own ways, but I believe having to adapt to so many new things, has definitely improved my skill in that regard. – Oliver

Of course, adjusting to life during the pandemic is only part of the picture, and much of what the apprentice above describes (new courses, new ways of thinking) would be relevant even under normal circumstances. Touching on similar topics, the apprentice below also demonstrates how they have developed the resilience – the ability to respond positively – that the framework describes:

The experience of the restructuring of my team and how I work helped me improve on my adaptability skill. Initially, I found the combination of being assigned a new manager and the change of working from home difficult, as it is in my nature to feel most comfortable in familiar settings or experiences. To tackle my discomfort with new experiences, I had to train myself to consider every new experience as

an opportunity to develop new or improve skills. – Adam

The following example also makes reference to working across multiple teams, which has required students to adapt to working not only with new people, but also within new technical environments:

> I've not only worked in different teams, alongside different team members, but I've also been involved in several different projects. Whilst working on these different projects I've been placed in multiple different roles, such as testing, UI development and backend API development. [...] The different environments and challenges that I faced have turned me into a more adaptable person while at the same time, giving me exposure to different roles within a development team. – Alex

The same apprentice goes on to provide a recent example of their adaptability being exercised and developed:

> The two senior developers that I had been working alongside and shadowing up to that point had both left the business and thus I was moved on to another project. [...] Not only did I have to quickly get to grips with the new programming language & framework, but also all of the different tools such as the IDE and even working alongside a completely different set of developers. I believe this experience has greatly improved my adaptability and ability to cope with sudden change. – Alex

It is clear from these responses that software engineering apprentices are required to adapt to a much greater range of experiences and environments than is the case on a traditional university degree programme. At university, the diversity of technologies, stakeholders, and practices is constrained by institutional resources and the practicalities of supporting standardised lab environments on campus.

D. Other meta-skills

'Communicating', 'Focusing', and 'Adapting' were the meta-skills most commonly cited by apprentices. However, in this section, we present examples of how the apprentices reported developing their other meta-skills, too. After the three meta-skills examined above, 'Initiative' was the next most prevalent. This meta-skill is also discussed under *Confidence* below, but examples of how apprentices report having developed or demonstrated their use of initiative include working more autonomously: "After the designs and requirements are finalised, I can take the feature and develop the full thing" (Noah). Another example involves an apprentice ensuring they had the skills required to undertake upcoming work: "I have familiarised myself with these tools in advance through completing the training provided internally, but also sharpening up my skills by completing the AWS [Amazon Web Services] Developer training pathway" (Theo). Other examples include generating "new ideas to communicate with technical staff, utilising existing technology and developing a new tool for

knowledge sharing" (Callum) and making suggestions about their own career development, "to take the initiative and reach out to management [...] and ask if I could 'shadow' one of their developers on the team" (Adam). 'Collaborating' was another frequently-cited meta-skill, again discussed under *Confidence* below. In one example, an apprentice refers to the initial challenge of collaborating with a team mate, which they subsequently overcame:

> The other apprentice and I had some teething issues at the start, such as getting used to each other's way of working, how to frame questions to get the answers we wanted to and learning how to teach each other concepts, as we were designing different parts of the application. In the end our different strengths allowed us to create a symbiotic relationship, teaching each other as well as tackling issues as a pair. – Lewis

Another apprentice describes initially preferring to work on their own, but noting that "this has quickly changed thanks to experiencing various forms of collaboration such as pair programming and even just discussing and communicating my own work to others, asking for their opinions and how they would go about solving the problems" (Alex). Others have learned that developing relationships – or a network of contacts – is key to collaboration. For example, one apprentice now appreciates the value of getting to know their colleagues and talking about shared interests: "As a result, it became much easier to ask questions to one another when working on related tasks" (Isla). Another notes: "I realised a key part of collaboration: establishing professional connections with others and creating a network of people who you can look to if you need guidance in the future" (Muhammad). The 'Sense making' meta-skill was said to have been developed through working with large code bases, for example, "having to work on it, figuring out: how it connected to each application and through what means, its methods, functions, interfaces and variables" (Oliver); "To help myself understand and make sense of some of the work being done I made sure to have a look at as many code reviews as possible." (Luca). 'Critical thinking' was reportedly exercised in analysing existing code, too: "Having analysed both legacy code and the new code, I now feel like my critical thinking mind set has been refined" (Olivia); and in designing test plans: "Figuring out how a certain piece of functionality works and how I could potentially break this system to find defects" (Harris). For brevity, not all of the meta-skills are considered here, but it may be interesting to note how the least cited meta-skill, 'Integrity', was said to have been developed by the one apprentice who chose to highlight it:

> I have learned that having integrity, especially in the industry that I am in where client financial data is concerned, is imperative in being a good employee but also adhering to the code of conducts set out by our regulators. Additionally, I have learned [...] that as software engineers, we have a duty of care

in that we must call out issues or problems if we see them – this may include reporting misconduct, misuse of software and equipment, or suspected criminal activity. This understanding is useful to me as a practitioner because it instils good practice and values when working and encourages me to live by my organisation's values as well as my own. – Ameila

E. Confidence

As noted above, inductive analysis of these data suggested that improved *confidence* was an important factor in the apprentices' development. Indeed, the apprentices discuss confidence in relation to the development of many meta-skills, indicating that confidence, perhaps, is what underpins perceived gains in their ability to communicate, adapt, and so on. At the very least, confidence appears to be closely coupled with the development of other meta-skills in the workplace. Lucas, for example, notes that "setting up calls with team members and communicating with them through these calls has helped me to be able to have the confidence to reach out to others for help with my work". The same student adds that this increased confidence in his ability to communicate means "I have become better at explaining my issues to my team, which makes it easier for my team to help me whenever I need it". For others, the significant number of meetings in which a working software engineer is expected to be involved has highlighted the connection between improved confidence and better communication: "my communicating skills and confidence have improved with these regular meetings" (Elijah). Other students tell a similar story:

> When I had just started in my role, I felt that my contribution to the meeting was minimal, as I hadn't had a lot of confidence in speaking and in my role. However, as time progressed, and I grew in confidence in my ability. I found myself contributing more and more, calling out blockers and asking for help when required. This resulted in me getting much more out the meeting. – Jamie

> I feel my confidence has increased which has then led to my communication improving. I have now built relationships with colleagues and also customers. I now take part in team meetings, and also hosted them. But, the most important thing for me is that I can now go into any call and have the confidence to speak and sound assured. – Finn

Closely related to 'Communicating' is the meta-skill of 'Collaborating', with both meta-skills falling under the umbrella of 'Social intelligence' on the meta-skills framework. It is no surprise, then, that these meta-skills are often mentioned by apprentices in tandem. However, the responses here illustrate how the ability to both communicate and collaborate may be connected to confidence. For example, Zara notes that she is "still working on" her "collaboration and the confidence to speak up in an intimidating room". However, she has already made good progress on this front, as she explains:

> I feel as though I can now collaborate with my team about ideas and problems. Through observing my first year and watching how everyone interacts and communicates I think helped me become more confident in collaborating with my team and putting my suggestions out there. – Zara

The 'Leading' meta-skill also connects to social intelligence, and to confidence. Jamie, for example, reports that his leadership skills have improved as a result of assuming "a very prominent leadership role" on a particular project:

> An advantage of this that I have noticed in my everyday life is that it has significantly increased my confidence. Not just in work situations but even in general social situations. [...] I look to continue developing this skill as much as I can. As it is one of the most vital skills to have in life. I aim to do this by trying to take on more of a leadership role wherever I can. – Jamie

Another of the meta-skills most commonly cited by apprentices – the ability to adapt – has been exercised by the fluid, heterogeneous nature of their role in the workplace. For example:

> Having experience performing multiple roles and utilising different technologies gave me confidence in my own ability to adapt and pickup new skills which has actually improved my ability to do so going forward. Facing problems within different teams and witnessing different team members' solutions to said problems also taught me that there are always multiple ways to approach a problem which has improved my resilience when facing challenging problems. – Alex

This is a recurring theme in the apprentices' responses, with another student making very similar observations:

> My ability to adapt will continue to develop as I carry on working on projects and get exposed to new systems and technologies. I can also actively get involved with changes in the workplace as to become more confident in my abilities and get past my hesitation. – Leo

Indeed, Leo goes on to say that he has asked "to transition to a different team in my department, which will allow me to learn their processes and systems and adapt to them". This demonstrates that Leo sees the value in being forced to adapt to new environments, and, perhaps, indicates a degree of confidence in making such a request.

The 'Adapting' meta-skill falls under the 'Self management' heading on the framework, alongside 'Initiative', which incorporates "courage" and "self-belief", amongst other aspects – perhaps underlining the degree to which these meta-sills are interconnected, given the clear connection with confidence here. For example:

> At first, I did not feel confident to do my own development work, as I was nervous to add code

to the codebase in case I broke the existing software. Having peer and mob programming sessions increased my development skills, which therefore led me to feel more confident in my work. Subsequently, I now feel like I can take my own initiative and do not need as much hand holding as I did at the start of the project. – Olivia

In another example, the connection between the 'Initiative' meta-skill and confidence is equally apparent:

As my confidence in developing solutions within [the team] grows, I have also been able to take more initiative when solving problems. For example, in our most recent release, we had a high priority production issue flagged, but there was insufficient resource for a more senior developer to investigate the issue right away. I was therefore able to volunteer to investigate the issue in the meantime and share my thoughts as to how we should resolve the problem. – Theo

Another student makes an explicit connection between confidence and initiative, in this case noting that a lack of the latter can translate into a lack of the former, with wider implications for their professional development:

I haven't always shown initiative as I lacked the confidence to try and fail. When I began at [my company], I preferred being micro-managed as I was starting a whole new career, with little prior experience that would be relevant to the role. This lack of confidence affected my ability to learn on the job and build working relationships within the company. – Adam

Those meta-skills associated with what the framework terms 'Innovation', such as 'Creativity' and 'Curiosity', were less prevalent in the apprentices' responses, overall. However, the role of confidence in developing these meta-skills remains apparent, even in the relatively slight data. For one student, a lack of confidence initially prevented him from suggesting creative solutions when discussing his team's code:

One of my weaker meta-skills has been my creativity, most notably speaking up in meetings, this was mainly due to self-confidence and inexperience when I was new to the role. As I have gained more experience and developed in my role, I have been more vocal in meetings and discussions with other team members about my opinions on team processes and about our code bases. Which has allowed me to give valuable input to the project and suggest options that the team might not have considered. – Charlie

Another student makes a similar point about using his creativity to suggest a process improvement to his team. He anticipates that, as he becomes more confident, he will also be able to make creative suggestions about aspects of the code itself, and not just the process of developing it:

I am sure with time, my creative skills will improve as I am exposed to more projects within the work-

place and as my programming skills improve though my university learning. As my confidence grows in these areas, I will surely develop my creative skills towards not only software development practices but also software programming. – Harris

Confidence also interacts with innovation-related meta-skills in smaller ways, for example, in exercising curiosity by asking questions: "I should continue to be confident in asking questions, engaging in meetings and not stop at just the face value of this information" (Liam).

Previous work has suggested that CS students' perceptions of professional programming practice can negatively impact their self-efficacy, which may be defined as an individual's confidence in their ability to complete a task [13]. Here, apprentices are gaining first-hand *experience* of professional programming practice, while simultaneously developing a range of meta-skills that they associate with confidence. Indeed, other recent work suggests that providing "opportunities for professional advancement" outside of the classroom may be effective in enhancing CS students' skills and confidence [14]. Prior work has also highlighted the potential for work-based CS programmes to develop "applied technological skills and professional self-confidence" [15] and for work placements to enhance academic achievement on technical degree programs [16]. Our findings lend further support to the idea that CS degree programs should incorporate opportunities for professional experience, with work-based apprenticeships providing such confidence-boosting opportunities in abundance.

IV. CONCLUSION

The data presented here illustrate how students developed their meta-skills while working as apprentice Software Engineers. Many examples cited by students relate to specific aspects of Software Engineering practice; for example, developing communication skills by participating in stand-ups and retrospectives. The means by which these employability skills have been exercised are often difficult to reproduce in a university setting; for example, working with multiple teams on multiple projects, simultaneously. A significant emergent theme that appears to underpin the development of many of these meta-skills is confidence. Here, two-thirds of the students made reference to increased confidence as a result of their workplace experience, and linked this increase with the development of several meta-skills. Future work might investigate the development of these meta-skills from a more quantitative perspective, or using means other than self-report. Such work might also further explore the role of confidence in meta-skills development, and examine the directionality of the relationship between confidence gained and skills developed in the workplace.

In summary, this work provides evidence of how a Software Engineering apprenticeship may develop specific employability skills, also known as meta-skills. It supports previous reports of the benefits of work-based learning in computing education, and suggests that apprenticeships may help address the employability skills deficit in CS graduates.

REFERENCES

[1] S. Fincher and J. Finlay, "Computing graduate employability: Sharing practice," Council of Professors and Heads of Computing, Tech. Rep., Jan 2016, publisher: Council of Professors and Heads of Computing. [Online]. Available: https://cphc.ac.uk/2016/01/08/cphchea-report-computing-graduate-employability-sharing-practice-published/

[2] N. Shadbolt, "Shadbolt review of computer sciences degree accreditation and graduate employability," Department for Business, Innovation & Skills, Tech. Rep., May 2016. [Online]. Available: https://www.gov.uk/government/publications/computer-science-degree-accreditation-and-graduate-employability-shadbolt-review

[3] E. Taylor-Smith, S. Smith, K. Fabian, T. Berg, D. Meharg, and A. Varey, "Bridging the digital skills gap: Are computing degree apprenticeships the answer?" in *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education*, ser. ITiCSE '19. Association for Computing Machinery, Jul 2019, p. 126–132. [Online]. Available: https://doi.org/10.1145/3304221.3319744

[4] S. Dziallas, S. Fincher, M. Barr, and Q. Cutts, "Learning in context: A first look at a graduate apprenticeship," in *21st Koli Calling International Conference on Computing Education Research*, ser. Koli Calling '21. Association for Computing Machinery, Nov 2021, p. 1–11. [Online]. Available: https://doi.org/10.1145/3488042.3490020

[5] Skills Development Scotland, "Skills 4.0: A skills model to drive scotland's future," Skills Development Scotland, Tech. Rep., Feb 2018. [Online]. Available: https://www.skillsdevelopmentscotland.co.uk/what-we-do/skills-planning-alignment/skills4-0/

[6] S. C. Barrie, "Understanding what we mean by the generic attributes of graduates," *Higher Education*, vol. 51, no. 2, p. 215–241, Mar 2006.

[7] M. Barr and J. Parkinson, "Developing a work-based software engineering degree in collaboration with industry," in *Proceedings of the 1st UK & Ireland Computing Education Research Conference*, ser. UKICER. Association for Computing Machinery, Sep 2019, p. 1–7. [Online]. Available: https://doi.org/10.1145/3351287.3351292

[8] J. Fereday and E. Muir-Cochrane, "Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development," *International Journal of Qualitative Methods*, vol. 5, no. 1, p. 80–92, Mar 2006.

[9] J. Swain, *A Hybrid Approach to Thematic Analysis in Qualitative Research: Using a Practical Example*. 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd, 2018. [Online]. Available: http://methods.sagepub.com/case/hybrid-approach-thematic-analysis-qualitative-research-a-practical-example

[10] B. N. Anderton and P. C. Ronald, "Hybrid thematic analysis reveals themes for assessing student understanding of biotechnology," *Journal of Biological Education*, vol. 52, no. 3, p. 271–282, Jul 2018.

[11] W. Xu and K. Zammit, "Applying thematic analysis to education: A hybrid approach to interpreting data in practitioner research," *International Journal of Qualitative Methods*, vol. 19, p. 1609406920918810, Jan 2020.

[12] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, p. 77–101, Jan 2006.

[13] J. Gorson and E. O'Rourke, "Why do cs1 students think they're bad at programming? investigating self-efficacy and self-assessments at three universities," in *Proceedings of the 2020 ACM Conference on International Computing Education Research*, ser. ICER '20. New York, NY, USA: Association for Computing Machinery, 2020, p. 170–181. [Online]. Available: https://doi.org/10.1145/3372782.3406273

[14] S. Rosenthal and T. R. Chung, *A Data Science Major: Building Skills and Confidence*. New York, NY, USA: Association for Computing Machinery, 2020, p. 178–184. [Online]. Available: https://doi.org/10.1145/3328778.3366791

[15] N. Ramirez, S. Smith, C. Smith, T. Berg, B. Strubel, M. Ohland, and J. Main, "From interest to decision: A comparative exploration of student attitudes and pathways to co-op programs in the united states and the united kingdom," *International Journal of Engineering Education*, vol. 32, no. 5A, p. 1867–1878, 2016.

[16] F. Ceschin, R. Rakowski, and I. de Vere, "The influence of work placement on the academic achievement of undergraduate design students," *The Design Journal*, vol. 20, no. 2, p. 259–278, Mar 2017.