Towards Integrated Graduate Skills for UK Computing Science Students

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ABSTRACT

In preparing computer science students for industry, degree content often focuses on technical skills such as programming. Such skills are essential for a successful post-study career in industry and is popular with students. However, industry notes that students are often limited in what can be referred to as graduate attributes or transferable skills. Such skills include effective teamwork, communication, and critical thinking, among others. Computing science students can also struggle to identify the value in these skills.

To address this gap, it is proposed graduate attributes are incorporated into summatively assessed coursework alongside essential technical skills. The overall aim is to develop a framework for computing science educators which will allow them to incorporate such skills more explicitly through assessment. As an initial step, this paper presents a review of graduate attributes from Russell Group Universities to identify common themes. These skills are summarised with an initial proposal for how some of the most common attributes could be incorporated into coursework assessment.

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1 INTRODUCTION

Transferable skills or graduate attributes are a key part of any degree. Skills such as effective communication, problem solving and the ability to work in a team are required to thrive in the workplace. In computing science, scaffolding students in developing these skills and developing their appreciation of the value of such skills can be challenging. Industry highly value such skills, but are noticing a skills gap [36] and consequently are developing their own training programmes to deal with the perceived lack of ability [5].

This paper presents an initial review and analysis of graduate skills identified by UK Russell Group universities. This initial review is then used as a starting point to identify key graduate skills which could then be incorporated into computing science assessments to aid development. The eventual aim of the work is to develop a framework of patterns for incorporating graduate skills into computing science curricula.

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2 BACKGROUND

In computing science degrees, a strong focus is often placed on meeting industry expectations. Students are supported in developing technical skills such as programming, software design, and databases. Industry also values non-technical skills such as communication and team work, without which students may struggle to gain or retain graduate employment. UK universities often address this balance through transferable skills, also referred to as graduate attributes. These are skills which they anticipate all graduates should be able to demonstrate competency in, not just those with a computing degree.

Most UK universities have their own version of these skills. For example, Fung at University College London developed a framework which allows students to explore learning from a research led perspective and a key dimension is the ability to ”connect academic learning with workplace learning" [12]. Other universities claim attributes such as "independent and critical thinkers" (University of Glasgow [28]) and “effective and influential contributors” (University of Edinburgh, [26]).

Graduate level skills are also addressed in the Frameworks for Higher Education Qualifications of UK Degree-Awarding Bodies (FHEQ). At each level of the frameworks, transferable skills are identified as an essential part of the qualification. As the level increases, the students transferable skills expand to reflect a higher level of attainment such as decision making in complex contexts and being able to take personal responsibility and initiative [10]. The QAA subject benchmark for computing also explicitly identifies required skills. In particular interpersonal and team working skills, computational problem solving (critical thinking) and intellectual skills (critical analysis, ability to make judgements and adaptability) [11].

The British Computer Society (BCS) degree accreditation aligns with the QAA benchmark, and identifies transferable skills as requirements for accreditation. This includes "problem solving, working with others, effective information management and information retrieval skills, numeracy in both understanding and presenting cases involving a quantitative dimension, communication skills in electronic as well as written and oral form to a range of audiences and planning self-learning and improving performance as the foundation for on-going professional development" [2].

In spite of these efforts and the increase in CS graduates (e.g. HESA data shows an increase of 11080 students studying computing in 2020-21 compared to 19-20 [17]) there is a lower employment rate of CS graduates. The Shadbolt review of Computer Sciences Degree Accreditation and Graduate Employability in 2016 reviewed Computing Science English Higher Education provision in an effort to understand why computer sciences undergraduate students in the UK suffered from a lower employment rate [39]. In particular, stakeholders were consulted on what made graduates less employable. One of the key reasons identified was a lack of well developed 'softer' skills such as communication and critical thinking. This resulted in a recommendation that HE providers should consider opportunities to ensure students develop transferable skills alongside their academic studies.

In recent years, there has been work exploring the incorporation of graduation skills in the computing curriculum.

For example, Groeneveld et al. et al. reviewed non-technical courses within CS programmes across Europe, examining the syllabus to identify transferable skills. A key finding of this research was that such skills are embedded in the CS curriculum according to the syllabus. This paper takes a different approach to identifying a set of transferable skills as it explores graduate skills through a University lens using thematic analysis. This allows us to capture any skills which may not explicitly be covered in syllabus information for CS programmes, but are important to Universities and could be seen as valuable by employers. Of the skills identified by Groeneveld et al. et al. presentation skills, give/receive feedback, accountability and conflict resolution did not fall within the themes identified and reported in Section 4 [14]. Thus there was substantive cross-over between skills for all graduates and those identified through the analysis by Groeneveld et al. et al.

Carter notes two general approaches to incorporating these skills, one is to have it embedded across the programme or alternatively create a specific module to cover such skills. The single module approach is undesirable, as Carter notes the challenge of incorporating these skills into a specific module addressing this due to students perceptions that they are being taught skills they already know. Carter suggests incorporating written reports and documentation into technical exercises to develop student skills.

Additionally, Hoffman et al. et al. report on a project to incorporate communication skills into the computing science curriculum ([19], [18]). Through this work, a range of strategies for incorporating communication into computing curriculum were developed. For example, use of scenarios in software development project modules which require regular reporting to 'supervisors' [18]. This paper is an initial step to achieve a similar objective for a wider range of skills.

Graduate attributes are often designed to reflect abilities of all students graduating from the respective university. However, there is evidence that computing science graduates frequently lack such skills. This can be seen in the QS report which explores the Global Skills Gap [36]. QS interview employers across the world in regards to new graduates transferable skills. Technology focused employers indicated the three most important skills were teamwork, problem solving and flexibility/adaptability [36]. However, the three main skills gaps in the 2019 report were in problem solving, creativity, and communication. Highlighting that despite effort to incorporate such skills, students are not demonstrating these competences well. In contrast, employers were most satisfied with technical skills, teamwork and flexibility. Technical skills is perhaps unsurprising, as students engage well with these and they are directly assessed. Teamwork is arguably unsurprising, as most degree programmes have required elements of group work which are also often assessed. This is often due to accreditation requirements, such as with the British Computing Society (BCS). Students require a degree of flexibility to navigate a range of topics and lecturers as well as general challenges encountered throughout a degree which perhaps also explains why students are demonstrating flexibility in the workplace.

When looking at CS graduates in particular, Haddad performed an assessment of recent graduates cognitive abilities by asking them to complete a case study. Haddad noted several skills which were lacking, including lack of reasoning (recent graduates had a single approach to problem solving) and analysis (recent graduates often thought of code first, rather than analysing the problem at an abstract level). Radermacher et al. also researched the skills gap with computing graduates by interviewing 23 employers about the perceived lack of cognitive abilities of new hires. As well as technical skills, graduate skills such as communication, problem solving, and teamwork were also identified.

Young argues that computing science degrees (Graduate Apprenticeships specifically) should be more explicit in incorporating such skills. However, there are particular challenges in getting computing science students to engage in activities which develop these skills. Employers of computing graduates note that they do not have sufficient transferable skills such as communication [3]. Indeed even technical skills are sometimes lacking. This is evidenced by Eckerdal *et. al* where computer science students nearing graduation were given a system to design, and were unable of doing so [9]. This could be attributed to the focus on technical skills and a get it working mentality [8] as well as the challenge of applying problem solving skills to a new context [13].

As a result of this perceived gap [36] technology companies are developing and delivering their own intensive training courses for new graduates. For example, Microsoft have developed training to bridge this gap as new graduates are lacking key skills and attributes [5]. It is clear in computing science degrees such skills need to be more explicitly designed into the degrees, as argued by Young [44]

This paper presents an initial exploration of graduate attributes for computing science students within the UK from a University perspective. It proposes initial suggestions of incorporation of such skills into summative assessment alongside technical skills since summative assessment has been shown to motivate student engagement, particularly if similar assessment is repeated [45].

3 METHODOLOGY

Given the UK context of the paper, it was decided that U.K. Russell Group Universities were an appropriate set of Universities to explore. The websites for each University were explored to identify any graduate attributes. It should be noted that there may be some Universities with graduate attributes which are not externally advertised through the website which is a potential limitation of the work. There are a total of 24 Russell Group Universities. Of the 24 universities in scope for the analysis, a total of 15 universities were identified as having graduate attributes from their websites. These were as follows: The University of Birmingham [23], The University of Bristol [24], The University of Cambridge [25], Durham University [41], The University of Edinburgh [26], Exeter University [27], The University of Glasgow [28], Imperial College London [20], King's College London [21], The University of Leeds [29], Liverpool University [30], The University of Manchester [32], Newcastle University [33], Queen Mary Belfast [31] and the University of Sheffield [34].

PROFESSIONAL PRACTITIONER	15
GLOBAL CITIZEN	12
CRITICAL THINKING	10
ETHICALLY CONSCIENTIOUS	10
TEAMWORK	10
PROBLEM SOLVING	8
COMMUNICATION	8
CONFIDENCE	7
SUBJECT SPECIALIST	7
REFLECTIVE	6
ADAPTABLE	6
RESEARCH SKILLS	5
DIGITAL LITERACY	5
LEADERSHIP	5
SKILLED BEYOND DISCIPLINE	4
COMMERCIAL AWARENESS	4
ANALYTICAL	4
INDEPENDENT THINKERS	4
INNOVATIVE	3

Table 1

To determine overlap of graduate attributes across these Universities, an inductive thematic analysis methodology was used, meaning that the themes were identified from the data rather than approaching with pre-defined perceptions.

The process followed is that proposed by Braun and Clarke [4].

(1) Familiarisation with the data
(2) Generating initial codes
(3) Generating initial themes
(4) Review themes
(5) Defining and naming themes
(6) Reporting

Firstly, a list of the graduate attributes according to each University was documented using their own wording. This was gathered from externally facing websites, and as such may be limited as some Universities may only have internally identified graduate attributes.

Each author independently examined the data to become familiar with it. Initial codes were then generated independently by each author based on their review of the data. Each author then examined their own codes to develop themes independently. The authors then met to review and compare independent codes and themes in order to identify and define the final themes for reporting in this paper. Once a final code book had been identified, by resolving any discrepancies and discussing reasoning behind codes, the data was then coded using the consensus themes. Inter-rater reliability was not calculated on the basis that there were little differences in the labelling of graduate attributes given the frequent re-use of the same terms across universities e.g. global citizenship. The results of this process are reported in Section 4.

4 ANALYSIS

The thematic analysis of the graduate attributes for the set of Russell Group universities resulted in the themes and frequencies outlined in Table 1.

The most common graduate skill identified was that of 'professional practitioner' (see Table 1). This theme was defined as attributes related to professional practice, but not sufficiently substantial to warrant an independent theme. For example, attributes such as self-management (e.g. Bristol [24]) , self-awareness, equipped for future challenges (e.g. Cambridge [25]), and life-long learners (e.g. King's [21]) were included in this theme This was an interesting attribute, as it is clear universities are beginning to recognise the need to develop students capable of fulfilling future job roles which may be currently undefined. Fundamentally this was considered as an expectation that graduates will behave in a professional manner.

The second most frequent theme was global citizenship which appeared in 12 universities out of 15. This was defined as any attribute which referred to an appreciation of society, inclusive of its variety of cultures and diversity. The University of Exeter define to Global Citizenship as a "commitment to actively engage in society, an awareness of sustainability issues, and an understanding of the cultures and view of others in the world, and a desire to further the common good". This was seen across other universities in forms such as "world citizens" [21] and "Globally and locally culturally aware" [23].

The third most frequent theme was a tie between critical thinking, ethically conscientious and teamwork which each occurred 10 times. Critical thinking and teamwork skills are not unexpected and have been discussed in the literature survey. Ethically conscientious perhaps reflects the shift in society towards reducing inequalities and improving quality of living for all. This is shift is reflected in the United Nations Sustainable Development Goals which covers aspects such as climate action, responsible production and consumption and reduced inequalities (see https://sdgs.un.org/goals) Teamwork was also reflected in the literature review, but is one area employers feel satisfied in the ability of recent graduates [11].

The remaining themes identified in Table 1 are mostly self explanatory. The one exception is perhaps digital literacy, which was encompassed attributes such as data skills, confidence in working with information and quantitative skills. This perhaps reflects the increase in big data, and its uses across many areas of our lives.

Further to the breakdown above, it was also considered that the identified themes could be grouped into three general categories; hard skills, soft skills, and personal qualities. Hard skills were identified as technical tasks such as data analysis, subject knowledge and research skills. Soft skills were identified as non-technical skills which help improve productivity within the workplace, such as good communication. Personal qualities were identified as qualities which can be attributed to an individual's personality such as being reflective. The result of categorisation is shown in Table 2. Of particular note is that the soft skills and personal qualities accounted for 15 out of the 19 themes. Soft skills and personal qualities are also almost equal in number, with soft skills having only one more theme than personal qualities. This reflection helps us see how valued non-technical skills and qualities are, however implementing this into programmes can be a challenge in computing science. The next section presents initial observations on how some of the more common themes identified can be built into computing science curricula.

Hard Skills	Soft Skills	Personal Qualities
digital literacy (5)	commercial awareness (4)	adaptable (6)
research skills (5)	communication (8)	confidence (7)
subject specialist (7)	professional (15)	analytical (4)
skills beyond discipline (4)	critical thinking (10)	ethically conscientious (10)
	independent thinker (4)	global citizen (12)
	teamwork (10)	innovative (3)
	leadership (5)	reflective (6)
	problem solver (8)	

Table 2: Categorisation of Graduate Attribute Themes

5 DISCUSSION

As a result of this analysis, we focus on professional practitioners, global citizenship, and critical thinking. The rest of this section addresses each in turn, highlighting potential approaches to incorporating these more explicitly into the computing curriculum.

5.1 Professional Practitioner

Any career requires professionalism, and computing science is no different [38]. Raj et al. argue that professionalism in computing science can include elements such as interpersonal communication with colleagues as well as programming with extensibility and readable code. It is also proposed that peer review of code and reflection on how they provide such a review could be helpful in establishing opportunities for professionalism. It is recognised by Raj et al. that it can be difficult to generate and scaffold opportunities to develop such skills, but even so they remain important.

5.2 Global Citizenship

Global citizenship is an important skill in a modern world. Citizenship is reflected in the SQA Higher Computing Science specification as well as the GCSE Computer Science specification. Students should be respectful of the variety of cultures and diversity, be conscious of sustainability and contribute to the community.

This is arguably a challenging aspect to incorporate into computing science assessment, however as argued by Yadav et al. et. al it is an important one [43]. Yadav et. al propose four steps as follows:

(1) collaborate with the community
(2) collect data as citizen scientists
(3) consult on potential solutions with the community
(4) take informed action with the community such as development of a technical solution

This could perhaps be achieved through project courses which emulate charity coding events such as those run by coding for good (https://www.coding4good.net/about).

Another approach is to explore technical solutions which have citizenship incorporated into their design, e.g. exploring the citizenship in electronic voting or blockchain, such as the work by Watanavisit and Vorakulpipat [42].

Students could also be asked to research and reflect on global citizenship in CS, for example exploring a real world case study on how diversity impacts on computing practice such as bias in AI demonstrated through automated recruitment by Amazon [1]. Students could also be asked to discuss and reflect on the issues which are demonstrated within such case studies.

5.3 Critical thinking

Critical thinking is a skill which was identified as lacking in recent graduates [11], but critical to a strong employee [16]. This importance is reflected in the position of this skill in our review.

Günay et al. presents research on increased critical thinking in software development students by delivering a capstone project which requires development of a solution to a real world problem which currently has no solution [15].

O'Neill and Hansen presents the re-design of a module to emphasise critical thinking by asking students to engage in analysis of a problem through creation of computing artefacts such as data analysis, code or statistical analysis [35]. Of particular note is the use of marking rubrics, which specifically reflect the level of competence demonstrated in skills such as analysis.

Rubrics are particularly useful for assessment of graduate skills such as this given their descriptive nature which allows behaviours to be described rather than relying on technical or otherwise functional elements for students to achieve. Raj et al. also propose rubrics as helpful for measuring competencies which align with the terminology of graduate skills such as interpersonal communication [38]. Other examples include work by Cicek et al. where the development of a number of rubrics which assess graduate attributes within an engineering curriculum [7].

An additional mechanism which aids in critical thinking and is well documented in computing education is peer review. It has often been used for code review (see [40] for a review) but also for other areas within computing (e.g. cyber security [22]).

5.4 Marking Rubric Examples

Having identified mechanisms to incorporating graduate attributes into assessment within computing science, we now present examples of marking rubrics which demonstrate one approach to evidencing these. 3 provides an example of a rubric which aims to reflect levels of achievement of professionalism for a capstone undergraduate project.

4 provides a subset of the marking scheme for a 4th year undergraduate exercise focused on analysis of a real world case study which demonstrates how a lack of inclusivity in the development of software systems can impact society. In particular, the criteria of problem recognition and understanding of social impact aligns with the global citizenship theme. It also provides an example of incorporating critical analysis, as students were expected to critique sources of information e.g. where sources were unreliable, or inaccurate in their assessment of the incident. It should be noted that this type of exercise can be challenging for students who have more experience of coding and technical exercises. As such, it is important to scaffold their learning to enable them to understand what is being asked of them before tackling the assessment. This could be achieved in a number of ways, e.g. critique of a submission from previous cohorts.

Classification	Descriptor
Fail (<40%)	Student did not engage with the supervisor.
3rd (40-49%)	Student's engagement with the supervisor is likely to have been limited. They are unlikely to have taken responsibility for the project, and have demonstrated limited professional characteristics. They have likely mismanaged their time, e.g. resulting in a last minute rush to write the dissertation or implement their project.
2:2 (50-59%)	Student has engaged with the supervisor in a satisfactory manner. There is significant room for improvement. For example, they could seek the supervisor's advice more, arrive on time to meetings, initiate more discussion and take more responsibility for their project.
2:1 (60-69%)	Student engaged with the project and supervisor in a mostly professional manner. They were generally dedicated to their work and approached many aspects in a methodical and thorough manner. The student demonstrated that they were self-motivated and could took initiative in their own work.
1st (70-100%)	Student engaged with the project and supervisor in a highly professional manner. They were dedicated to their work and approached all aspects in a methodical and thorough manner. The student demonstrated that they were self-motivated regularly demonstrated strong initiative in their own work.

Table 3: Demonstrates classification descriptors for student professionalism within a capstone project

6 CONCLUSION

In this paper we have presented a thematic analysis of graduate attributes of Russell Group Universities. From this, we identified 19 graduate attribute themes, which we categorised into three areas; hard skills, soft skills and personal qualities. We also explored the literature and presented a range of techniques to incorporate the top three most frequent graduate attribute themes (professional practice, global citizenship and critical thinking) into computing science curricula.

It is clear from this review, that graduate attributes are a key element of computing science degrees. The challenge lies in ensuring students recognise the value in developing these skills. Whilst we may not be able to ensure appreciation of these skills, we can encourage engagement by use of assessment rubrics which explicitly incorporate the themes. Three of the most common graduate attributes were examined in more depth, with an initial proposal for incorporating these attributes into a rubric.

It is worth noting there are some potential limitations of this work. It is possible some Universities were identified as having no graduate attributes if they were not shown on a public website. The work also only focuses on Russell Group Universities as a starting point, and thus frequencies when expanding to examine more Universities may be different.

The planned next steps involve developing these approaches further, and establishing practice for the remaining graduate attributes. These will then be combined into a framework which computing science educators can use to design assessment incorporating any skills identified through this analysis. It is also planned to survey computing science student perceptions of these skills, and how they are developed within different institutions, as well as trying to established the effectiveness of including such skills explicitly in assessment.

Criteria	1 Point	2 Points	3 Points	4 Points	5 Points
Problem Recognition and Understanding of Social Impact	Minimal recognition and understanding of the problem and its impact on society.	Weak understanding of the problem given the context of the case study. Minimal identification of concerns and impact on society.	Identification of problem and related understanding is good, there are likely 1 or 2 significant areas for improvement.	Very good identification of the problem given the context. Very good understanding of the problem, likely one or two small areas for improvement.	Excellent identification of the problem given the context of the case study. Strong understanding of the problem given the context of the case study. Excellent understanding of the key concerns and impact on society as well as a reflection on how such issues can be avoided.
Critical Analysis	Minimal evidence of critical and independent thought as applied to the case study.	Adequate demonstration of critical and independent analysis.	Good demonstration of critical and independent analysis, but it is likely limited to one or two aspects.	Very good demonstration of critical and independent analysis. Could be improved slightly in one or two small areas.	Excellent demonstration of critical and independent thought, no room for improvement in the given context.

Table 4: A rubric reflecting global citizenship

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