DEVELOPING AN UNDERGRADUATE COMPUTER SCIENCE CURRICULUM; EMBEDDING PROFESSIONALISM

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Abstract

This paper discusses the challenge of integrating professionalism and professional issues into the design of an undergraduate Computer Science curriculum. Undergraduate curriculum design is increasingly a multi-stakeholder process with input from industry, current and future students, domain experts and academics. Courses also need to pass a viability test which requires financial and logistical planning, marketing input and forecasts of student numbers. For subjects where professional bodies have a regulatory role, such as medicine, professional standards are an integral part of the curriculum design. For subjects such as Computer Science, where professional bodies do not have a regulatory role, the status and contribution of professional standards to curriculum design is less clear. However, there is an industry expectation that students who complete an undergraduate computer science course will have an understanding of the professional issues in their domain and there is a requirement for university courses to ensure that students are fully equipped to work in their chosen profession. Many undergraduate Computer Science courses have accreditation from the relevant professional body.

Integrating professional issues into the Computer Science curriculum presents three key challenges. Firstly, there is a need to define what is meant by professional issues and whether this is separate to, or part of, the wider topic of professionalism. Secondly there is the pedagogic challenge of making professional issues accessible and relevant to undergraduates and developing the concept of professionalism. Thirdly, there is the design challenge of incorporating professionalism and professional issues into a changing curriculum.

In this paper we discuss the professional standards that apply to the design of Computer Science undergraduate courses. We argue that the complexity of the curriculum design process means that professionalism and professional issues must be explicitly identified as a key element in the curriculum to ensure that these components are not overlooked. We describe the process of embedding professionalism in the curriculum and the review process that will be used to monitor the effectiveness of the curriculum design.

Keywords: Computer Science, Professionalism, Curriculum.

# INTRODUCTION

Curriculum design and teaching and learning practice in Higher Education are an active research area particularly in STEM (Science, Technology, Engineering, Maths) subjects such as Computer Science [1]. STEM subjects have been identified as being at the boundaries of curricula, that is, the curricula for these disciplines draw on theoretical and practical knowledge bases with a requirement to meet the expectations of both the academic and the practice communities [2]. We extend this to include the need to address the expectations of other stakeholders such as students and funding bodies. These factors together create what has been described as ‘multiple accountabilities’ [2] in that the curriculum must address issues such as professionalism and employability, which are additional to the purely academic requirements of the discipline. A further issue for Computer Science is the rate of change in the field, making the task of developing a manageable undergraduate curriculum particularly difficult [3]. For Computer Science education at first degree level, the challenge is to enrich the academic experience so that undergraduate students not only achieve their degree but are prepared for the reality of working as a computing professional.

In this paper we discuss the concept of professionalism in the Computer Science undergraduate curriculum and the incorporation of professionalism into the redesign of a Computer Science degree at a UK higher education institution.

The paper is structured as follows: section 2 discusses professionalism and professional concepts in the Computer Science undergraduate curriculum; section 3 discuses the approach used to embed professionalism within a Computer Science curriculum in a Higher Education institution. Section 4 presents the conclusions and suggestions for future work.

# PROFESSIONALISM IN THE COMPUTER SCIENCE CURRICULUM

## Defining Professionalism

Professionalism in its widest sense is linked to the concept of membership of a profession, conformity to a code of ethics and commitment to the rules and standards of the profession [4]. Professional culture is seen as a key part of professionalism and as helping to determine the nature of professionalism [5]. It is usual to distinguish between professionalism and professional issues in that professionalism represents the overarching concept while a professional issue may be one strand within the wider context of professionalism. This distinction becomes important when attempting to incorporate professionalism into the Computer Science curriculum; teaching and learning for professionalism requires a holistic approach in which professional issues are woven together to create a culture of professionalism as opposed to disconnected sessions on professional issues. There is also the pedagogic challenge of making professionalism and professional issues accessible and relevant to a student audience.

In some disciplines such as medicine, membership of the appropriate professional body confers a licence to practice but in other disciplines such as Computing, where there is no statutory requirement to belong to a professional body, professionalism refers more to the standards and behaviour expected of an individual working in the field. International and national professional organisations such as the Association for Computing Machinery (ACM) and the British Computer Society (BCS) promulgate codes of ethic and codes of conduct, with the expectation that these codes will set the standard for members of the profession. While some elements of the codes of ethics, for example those relating to whistleblowing may be applicable to any profession, the codes also include specifically computing elements, usually linked to technical obligations, such as the requirement to maintain awareness of technological developments in the BCS code of conduct [6] and the requirement, in the ACM code of conduct and professional ethics, to ensure robust security when developing systems [7].

Examining the ACM code of conduct and professional ethics and comparing this with the British Computer Society code of ethics four common themes can be identified. The first is the belief that the profession has a duty to promote the general good and to avoid behaviours which would damage that good. We describe these as societal responsibilities. The second is a commitment to professional responsibility which includes such obligations as technical competence, security, designing robust systems, compliance with relevant standards and legislation and critical awareness, ensuring that a professional does not undertake work beyond his/her competence. We identify communication as a third theme; communication is used here in its widest sense and includes communication skills, collaboration, collaborative working covering team working skills and including professional responsibilities to fellow professionals. The fourth theme is a commitment to continuing professional development and life long learning, particularly given the evolving nature of computing. Aligning the Computer Science curriculum with the themes identified from the codes of conduct, suggests a number of teaching and learning topics, summarised in table 1. This is an indicative list and is not intended to be fully comprehensive.

Table 1: Indicative List of Teaching Topics Linked to Computing Professionalism

|  |  |
| --- | --- |
| Theme | Topics to be covered in the undergraduate curriculum |
| Societal Responsibilities | Data Protection and privacy; Discrimination; Informed Consent; Intellectual property rights; Social Responsibilities; Professional Conduct Responsibilities; Environmental Responsibilities; Accessibility |
| Professional Responsibilities | Technical Competence; Self Evaluation; Reflection; Conducting Critical Reviews; Security and Robustness; Risk; Personal Responsibility; Compliance with legislation; Professional and Personal Ethics |
| Communication | Communication Skills; Communicating with different Audiences; Teamwork including working with and supporting colleagues |
| Currency | Continuous Professional Development; Awareness of current and emerging computing developments; reparation for Lifelong Learning;  |

The topics identified from codes of ethics and code of professional conduct suggest a professional curriculum. The following section looks at guidance for the Computer Science academic curriculum and the overlap between the Computing Science curriculum and the professional curriculum.

## Computer Science Curricula

Although there is no single national or international undergraduate Computer Science curriculum, there is a broad consensus as to the general topics which should be included. One of the best known sets of guidelines for the Computer Science curriculum is the ACM and IEEE-CS (Computer Society of the Institute for Electrical and Electronic Engineers) computing curricula for Baccalaureate programmes. The most recent update, the ACM/IEEE-CS 2013 Computer Science curricula [3] explicitly recognised the importance of professional issues, by introducing a new Knowledge Area (KA) covering Social Issues and Professional Practice [8]. The ACM/IEEE curricula stresses that technical skills alone are not sufficient to prepare undergraduates for the workplace and that soft skills, such as professional communication skills, are required to prepare students for the workplace and to support future career development [3]. Professionalism in [3] is not limited to a single KA. Computer Science graduates are expected to have a range of skills and characteristics which include a commitment to professional responsibility [3, p. 24]

In the United Kingdom, the Higher Education QAA (Quality Assurance Agency) provides subject benchmark statements for undergraduate degree courses. The QAA benchmark for Computing, which covers the whole field of computing including Computer Science, identifies three categories of skills that computing undergraduates are expected to acquire, computing-related cognitive skills, computing-related practical skills and generic employability skills [9]. All three categories of skills include topics which can be linked to the professional curriculum. Computer-related cognitive skills, for example, includes recognition of professional, social, moral and ethical issues; computer-related practical skills includes recognition of risks and safety aspects while generic employability skills include ‘soft skills’ such as communication and team work and self-management and reflection [9, pp. 10-11). A student who graduates with a UK Computing degree is expected to be able to work within a professional, legal and ethical framework and to identify mechanisms for professional development and life long learning [9, pp. 14]. The QAA benchmark statement explicitly recognises the role of professional bodies.

## Incorporating Professionalism into the Curriculum

In the context of teaching and learning, it has been proposed that to be real, professionalism “has to be something that people – professionals – actually ‘do’, not simply something that the government or any other agency *wants* them to do, or mistakenly imagines they are doing” [5]. The same comment applies to incorporating professionalism in a curriculum; listing an element on a syllabus is no guarantee of student engagement. Limiting instruction to a single course (module) can lead to students perceiving the skills as irrelevant to the subject as a whole [10]. Presenting professional skills as a discrete topic, or embedding them in only one module, creates the possibility that some students may avoid that particular topic altogether. Embedding professional skills in only one module also works against the concept of a professional culture, in that professionalism may come to be understood as a series of unrelated skills. [10] discuss the experience of embedding oral communication skills across a range of modules, using industry relevant scenarios, arguing that this develops the student skill set. A possible limitation of this approach is that it may sacrifice depth. Blume [11] proposes a more in depth strategy, arguing that although there is general recognition of the need to equip computing students with communication skills, these skills are not covered in sufficient depth and students benefit from acquiring skills in a dedicated module. Other approaches to embedding professional skills have involved trying to break down the education/industry barrier by embedding employer participation [12] and involving external stakeholders in projects [13]. As an alternative to bringing employers into the course, which we describe as an outside – in approach, [14] describe an approach in which professionalism is built into grading criteria, using marking criteria designed to reproduce an employer’s view. We describe this as an inside – out approach.

# Incorporating professionalism into a computer science curriculum

## Context

In the following sections we discuss the strategy adopted by the Computing Department of a UK higher education institution when redesigning the Computer Science curriculum. The redesign of the curriculum was triggered by a move away from the previous approach of having a number of separate degrees which shared some common modules, to a single Computer Science award which supports five different subject pathways. The motivation for the redesign was to enhance flexibility, integration and student choice and to ensure that the curriculum evolved to match the rapidly changing computing environment. In UK higher institutions, degree structures are revalidated on a 5 year cycle and the redesign was synchronised with the 5 year cycle.

In the Computer Science pathways degree, students will study a common first year and then select the modules which support their chosen pathway. Undergraduate awards consist of three years of taught study with an industrial placement year between the second and third years of study. Some students do not complete a placement year and instead proceed straight the final year of study. In each year of study, students study 120 credits, consisting usually of four 30 credit modules. Each module is defined by a module descriptor which defines the learning outcomes of the module, gives details of the assessment and the indicative content and provides other information such as method of delivery and resources.

The Computing department discussed here has a strong history of employer engagement supported by the use of an industrial placement year and has close links with a number of industry leader organisations. This is reinforced by inviting guest speakers from industry and the use of external organisations as clients for development projects in some modules. This supports an outside – in approach. At the same time the use of real world scenarios, the incorporation of professional criteria into assessments, for example assessments which are marked as management reports and close links with the university careers network support an inside – out approach. Support for professional certification is built into a number of modules and students are encouraged to take the relevant professional qualifications associated with these modules. Enrichment activities such as technical ‘bootcamps’ sometimes provided in association with industrial partners provide students with additional technical competences which can lead to further professional certification. Students are encouraged to attend local meetings of the BCS, the Chartered Institute for IT in the UK. These teaching strategies ensure that all students will have some degree of interaction with professional issues in the course of their studies. However, in order to ensure that every student interacts with the full range of professional issues, and to develop a culture of professionalism, it is necessary to build professionalism into formal teaching and learning activities. In the following section, we discuss how the four themes identified in 2.1, societal responsibilities, professional responsibilities, communication and life long learning, were designed into the Computer Science curriculum.

## Embedding Professionalism

The challenge in terms of creating a culture of professionalism was to ensure that the four professionalism themes identified in 2.1, were covered in each year of study and that professional issues were embedded across the range of modules so that all students are prepared for a career as a computing professional. A further issue was that student understanding of professionalism should be deepened and extended over the period of the degree and that the nature of professional issues would themselves change over time, as computing evolves. To address the problem described in section 2.3, where some students may avoid certain topics, professionalism was embedded in option modules but also in every core module across all three taught years of the degree, meaning that students cannot achieve the degree in any pathway without demonstrating competence in professional skills and issues. To ensure coverage and depth of understanding, professional issues were embedded into the learning outcomes and indicative content of modules. This supports assessments which evaluate, for example, communication skills as well as technical skills and do so in a way which is appropriate to the level of study. Topics are explored in greater depth and complexity at each level as students move through their studies

We illustrate the process through word clouds. The word clouds are derived from the module descriptors and are based on learning outcomes, indicative content and assessment. To support the creation of the word clouds, variations of a term have been standardised and some terms have been omitted or mapped to the nearest equivalent to reduce the size of the clouds. For example, variants of communication skills such as oral or written communication have been mapped to communication skills. Teamwork, which was identified as a communication topic in 2.1, is shown as a separate element. Technical competencies, although a key professional issue, are not included as the word clouds focus on other elements. This reduces the representation of issues such as quality and robustness. Fig. 1 gives the Wordcloud for communication in the first year and second years of study.



Figure 1 Wordclouds for first and second year of study

Some topics such as communication skills, teamwork, ethics and standards stand out in both the first and second year of study. However, there is a progression in terms of the complexity and balance of topics covered. The concept of the computing professional, as opposed to discrete professional issues, assumes greater importance in the second year. Subtopics, for example communicating to different audiences as a subtopic of communication and career planning and personal development planning as a subtopic of future work, become more visible. Ethics becomes more prominent and is extended by recognition of codes of conduct. In Figure 2, which gives the wordcloud for the final year of study, communication appears to have less prominence. This is because in the final year, more complex communication issues such as communicating to different audiences, communicating issues and the implications of technical decisions and communicating at the appropriate level are shown as distinct topics. Mapping these topics to a generic communication topic shows communication as one of the major themes. For the final year WordCloud, ‘Professionalism’ is used as the mapping term to cover concepts such as professional activity sessions and professional communication. The WordCloud for the final year shows greater complexity and specialisation of topics than in the first and second year of study, illustrating our view that professional skills and knowledge must be developed and extended over the course of the undergraduate degree.



Figure 2 Wordcloud for final year of study

One element not shown in the word clouds is the development of self-evaluation, reflection and critical review skills, identified in 2.1 as a key component of professional obligations. As students progress through the different stages of their degree, the computer-related cognitive skills discussed in 2.1, are also developed, linking to the revised Bloom taxonomy [15]. In the first year, for example, learning outcomes may be linked to knowledge, understanding and application. By the final year of study, learning outcomes are linked to elements such as critical evaluation, critical review and critical appraisal.

# Conclusions and Recommendations for future work

Curriculum design is a process of exploration, evaluation and review. The redesign of the Computer Science curriculum discussed in this paper was shaped by two factors: the need to equip students with the technical competencies and underpinning theoretical knowledge required to succeed in a fast changing computing environment and the soft skills, conceptual capabilities, employability characteristics, and professional and personal responsibilities and ethics which come together under the heading of professionalism. This paper has described the way in which professionalism was embedded in the curriculum through inclusion in the module outcomes and indicative content of module descriptors. The next stage of the process is to evaluate, in conjunction with students, staff, employers and the relevant professional bodies, the way in which the professionalism embedded in the curriculum is delivered in practice, to ensure that the curriculum continues to evolve to support students as they start their professional careers.

REFERENCES

1. R. Khatri, C. Henderson, R. Cole, J. Froyd, D. Friedrichsen,C. Stanford, C "Characteristics of well-propagated teaching innovations in undergraduate STEM." *International Journal of STEM Education* vol 4 issue 1 2017
2. S. Shay "Curricula at the boundaries" *Higher Education* vol. 71 issue 6 pp. 767–779 2016.
3. ACM/IEEE-CS Joint Task Force on Computing Curricula. 2013. Computer Science Curricula 2013. ACM Press and IEEE Computer Society Press. Retrieved from <http://dx.doi.org/10.1145/2534860>.
4. Professional Standards Council (Australia) "What is a Profession" retrieved from https://www.psc.gov.au/what-is-a-profession
5. L. Evans, “The ‘shape’ of teacher professionalism in England: professional standards, performance management, professional development and the changes proposed in the 2010 White Paper” *British Educational Research Journal* Vol. 37 Issue 5, pp 851-870 2011
6. British Computer Society Code of Conduct Retrieved from <https://www.bcs.org/category/6030>
7. ACM Code of Ethics and Professional Conduct Retrieved from <https://www.acm.org/binaries/content/assets/about/acm-code-of-ethics-and-professional-conduct.pdf>
8. S. Roach, S. & M. Sahami, M. "CS2013 Computer Science Curricula 2013" *Computing Education IEEE*  pp 114-116 March 2015
9. QAA Subject Benchmark Statement Computing 2016 retrieved from <https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/sbs-computing-16.pdf?sfvrsn=26e1f781_12>
10. K. Anewalt, J. Polack “A curriculum model featuring oral communication instruction and practice” *SIGCSE ’17* March 08 -11, 2017, Seattle, WA, USA.
11. L.Blume, R.Baecker, C. Collins, A. Donohue “A “Communication Skills for Computer Scientists” Course” *ACM ITiCSE’09* Paris, France 2009
12. P. Hanna, A. Allen, R. Kane,N. Anderson,A. McGowan, M. Collins, M.Hutchison, "Building professionalism and employability skills: embedding employer engagement within first year computing modules" *Computer Science Education,* vol. 25:issue 3, pp. 292-310, 2015
13. J-P Steghofer, H. Burden, R. Hebig, G. Calikli, R. Feldt, Hammouda, J. Horkoff,, E. Knauss, G. Liebel, “Involving External Stakeholders in Project Courses” *ACM Transactions on Computing Education*, Vol. 18, Issue 2, pp 8:1-8:32 2018
14. A. Armstrong, C. Wellington, “Work in Progress: Modeling Employer Assessments. Using professionalism in Computer Science Courses” *Proceedings, Frontiers in Education*, 3-6 October 2012 Seattle, Washington USA
15. D. Krathwohl, "A Revision of Bloom's Taxonomy: An Overview" Journal of Theory into Practice Theory Into Practice Vol. 41, No. 4, pp. 212-218 2002