Increasing academic diversity and inter-disciplinarity of Computer Science in Higher Education

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ABSTRACT

Computer Science education has changed significantly over the last decade, including UK national curriculum changes and the Office for Students' Institute of Coding, resulting in an increased focus on widening participation. Key stages 3/4 have moved away from ICT provision towards more rigorous Computer Science, while Higher Education has sought to draw in students who do not see themselves as future Computer Scientists nor see the relevance of those skills to their future careers.

We present the design for a 40 credit, whole-year programme at Lancaster University comprising one-third of a student's first year. Targeting non-Computer Science students with no previous experience, the objective is to develop realistic, practical Computer Science skills that students can independently apply to relevant problems in their major degree programme and future career. We focus on two significant aspects of the programme.

Firstly, the overall programme requires flexibility to accommodate studying in parallel with a student's major. Blended learning replaces lectures with online videos, slides, and quizzes, supported with face-to-face staff time in weekly studios designed around collaboration. We discuss overcoming the challenges this presents around motivation, engagement, equality, student support, and general course design. We also compare our year-long course design, intended to give practical inter-disciplinary skills across Computer Science topics, with recent literature mostly involving short-duration workshops or modules, usually heavily focused on programming.

Secondly, recruitment materials were carefully designed to encourage interest from an academically diverse range of major programmes that typically do not take Computer Science modules. Core to this was addressing the gender and social diversity challenges present, and to illustrate the impact Computer Science skills could have on other majors and society. We discuss the impact of our re-designed learning spaces and curriculum, along with the student diversity data, and staff feedback.

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CCS CONCEPTS

• **Social and professional topics → Professional topics**; *Computing education*; Computing literacy; Model curricula; User characteristics.

KEYWORDS

Computer Science, Higher Education, Digital skills, Diversity and Inter-disciplinarity

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1 WHAT IS IT?

Our new programme offers tailored computing modules to first year undergraduate students who come from an academically diverse background, all of whom have chosen a non-computing discipline as their major subject. Our aim is to give our students the digital knowledge and skills to make a positive impact on their major subject, on their future career and on society, by understanding and taking control of their digital world. This is achieved through a 40 credit, whole-year programme (one third of a student's first year) of creative and applied computing modules that are suitable for students with no previous computing experience. Initially students take core modules on computational thinking and an introduction to programming with JavaScript and Python, before they choose electives from courses including creative web applications, more advanced Python, the history and evolution of computing, making sense of data, digital making and crafting, information visualisation and virtual worlds. Students also undertake a five-week group project at the end of the programme, intentionally linked to the students' major subjects. These areas were chosen to cover a breadth of Computer Science topics that have potential applicability to any student's major subject, and can support a "deep-dive" into one particular aspect without requiring comprehensive knowledge of the rest. Flexibility in the programme is essential to accommodate studying these courses in parallel with a student's major. As such, blended learning replaces lectures with online videos, slides, and quizzes, supported with face-to-face staff time in weekly studios designed around collaboration.

2 WHY ARE YOU DOING IT?

New technologies and associated digital skills now have a significant role in our economy and society, to the extent that "digital skills are required in at least 82% of online advertised openings across the UK" [5, p. 8]. However, 88% of organisations across Great Britain admit that they "are currently lacking in digital skills, with many expecting these shortages to increase in the next five years" [11, p. 11]. Addressing this digital skills shortage is at the heart of the Institute of Coding (IoC) [3]. The Widening Participation theme (theme 4) includes amongst its aims: creating "courses that facilitate learning for everyone irrespective of age, gender, or experience"; initiating a culture change; improving the industry pipeline; and boosting the appeal of the curriculum [9]. At Lancaster University, gender inclusion has been a particular concern given our recent intake for Computer Science major students stands at 14.9% females and 85.1% males. However, the percentage of females in the cohort drops to 12.5% when we factor out joint degree programmes. If we look to the national HESA data for the most recent (currently 2017/18) data on gender balance, student enrolments for HE Computer Science courses stood at 17.6% females and 82.3% males [8]. Awareness and concern at these lower than national average figures led to Lancaster University forming a research group to investigate diversity in Computing Education. This work has surveyed international literature focusing on gender diversity, and worked with a colleague from The Open University to develop (currently draft) IoC guidelines to support the embedding of an inclusive approach to the teaching and learning of Computer Science and related disciplines at UK universities [7]. The guidelines take a holistic approach to inclusion, and include practical ideas and tools to help H.E. staff make tangible and sustainable changes to their practice and outcomes.

3 WHERE DOES IT FIT?

Our university has a large and diverse student intake across a wide range of degree programmes and incoming qualification types. Much of the student intake is from recognised areas of high deprivation. The university has experience in multiple outreach programs in areas of computing and technology. This work focuses on first year university students at Lancaster University. In this year, students take 80 credits of major modules (i.e., belonging to their degree programme) and 40 credits of minor modules. This provides an opportunity for students to study a different topic in depth and breadth for an entire year. In previous years, minor options in Computer Science were offered by allowing students to take modules that were part of the major, but these modules were not especially suitable for them. Institute of Coding funding offered the opportunity to undertake the design and implementation of a brand-new minor programme in Computer Science which could increase the diversity of the cohort of students with Computer Science experience by taking these skills "to them" rather than forcing them to commit to a CS major. It is long, covers a breadth and depth of Computer Science topics, its credit-bearing nature means it's taken seriously by students, and those students taking it are drawn from the full range of diverse degrees across the institution.

Compared to other digital skills courses, our programme is interesting for a number of reasons. The minor programme is delivered using blended learning[1]. This fulfills two purposes. The first is the practical aspect of avoiding difficulties in timetabling students from potentially every major in the institution into a single module. More importantly, it allows students to go through the course material at their own pace, in a more authentic manner[10, 12]. Since the aim is to have transferable skills that the students can apply on their own in their major programmes, being able to digest small individual concepts and understand their relations by themselves is a core competency. This part of the design is informed by Connectivism [14]. The large online component and the lack of face-to-face contact can be a problem in blended contexts and can present a risk of learner isolation. This re-enforces the need for quizzes and tasks that allow the learner to self-assess progress. Since physical space has an important influence on the mindset and interaction within a studio, we renovated our studio spaces to eliminate the stereotypical "rows of computer screens" and designed a space centered around student collaboration. Weekly two-hour studios are run with small groups (25 max) and low staff-student ratio (1:12). The minor programme has multiple module options within it; students taking different options mix in the same studio sessions to encourage inter-disciplinary mixing and incidental learning.

The use of blended learning also allows learner analytics of the online components. These can be used to monitor engagement in the minor, which can be a challenge alongside their major. Online components also deal with a number of diversity challenges around accessibility by having this material presented in the same way to every student with the ability to pause, repeat, and read transcripts. The large online component does present a risk of learner isolation, and so re-enforces the need for the face-to-face studio sessions mentioned previously. Short online quizzes are presented together with most concepts in the online delivery to provide students with an ability to self-assess their progress between studios.

The programme objective is to attract students choosing to study other major subjects from a diverse range of backgrounds (covering indicators such as gender and background) into the Computer Science minor. The advertising for the programme therefore needed to be designed around that goal. The key messages that were adopted were no previous experience required (removing fear that "it's not for me"), learning transferable skills which can applied into your major, and being able to make an impact of society with those skills. Visually, we decided to highlight gender diversity, collaboration, and applications of learnt skills being concretely situated in the major career field.

4 DOES IT WORK?

In October 2019, we recruited 72 students from different disciplines across the University. Of those, 39.1% were female and 60.9% male. This compares to 12.5% female (from 262 students) on our CS majors, and 14.9% female (from 335 students) on our joint programmes. Although we had hoped for closer to 50%/50%, our ratio is ~3 times better than the major programmes.

Students have three weeks to change between minors. In the first two weeks, seven students changed into our course and only one left. We intend to have brief one-to-one interviews with leaving students to identify why they decided to change and feed that into revision for the next year.

Table 1: Overarching design paradigm

Aim	IoC Outcome	Used in	Tools
Top level principles	Inclusion is embedded in policy, processes and practice	Creation, delivery and review of curricula	Workshops, training, audit, checklist
Diversity of learners	Recruitment of under-represented groups, especially women	Marketing and communications	Auditing and checklist
Diversity in content	Materials and content reflect diversity in language, visuals and case studies	Lesson planning and content development	Checklist for teachers and learning developers
Learning environments and methods	Diverse learners feel a sense of belonging and can succeed	Design and use of learning spaces - both physical and online	Checklist for developers and designers
Teaching diversity competence	Future tech professionals develop competence in inclusive practice	Content development, in course activities and discussion forums	workshops, examples and case studies

As part of our recruitment drive, we designed a course promotion video that explained the course and the mode of delivery. We conducted initial discussion with various departments in the University to understand their views and to solicit their support in advertising these modules to their first year students. Several non Science departments thought these will be useful for their students. Recruitment from Maths major students was particularly high. At the minor promotion event in Freshers week, student engagement was solid but it was optional and at the end of a long day, so only a minority of students attended. We observed that most students did not realise it had blended delivery and therefore no lectures but when told did not express strong positive or negative reactions.

During the registration day, a few extra students were recruited from a queue to sign up to a social sciences subject minor. A female member of staff talked to the mostly female students about our minor to kill time as they waited, causing three to change their mind and sign up. This suggests that a more face-to-face recruitment strategy would be successful. Unfortunately, students only arrived to the university a few days before, so there are no obvious opportunities for that, ignoring the obvious staffing requirements.

Feedback from staff has been encouraging. Everyone that has seen the video or heard about the course liked it. This confirmed the recognition that advanced digital skills are important across a wide range of degrees. There have been queries about post year one students enrolling and even if it would be suitable for staff development. Three Masters students studying Digital Humanities in the School of History are taking a subset of the minor programme as an introductory pathway to the digital skills required for elements of that field. This raised an interesting question of which level the modules "sat" at and whether that would count towards the required credit count for their degree requirements. Normally module difficulty would increase as the level increases but an introduction to Computer Science with no previous experience is going to be the same at any level; it is limited by the length of time required for the new concepts to be assimilated rather than their difficulty. Therefore, for any inter-disciplinary offering, careful consideration must be given to the formal level of the module(s) in order to be available to the maximum number of students.

5 WHO ELSE HAS DONE THIS?

A study conducted by Dawson and Allen [4] described the experiences and outcomes of non-computer science majors to be worst compared to those of computer science majors. They reported that course instructors described non-computer science majors as most likely to say they did not enjoy the course, that they are delivered quickly with higher workload. They predicted high dropout rate within their provision. In order to mitigate this high prediction, they design the course to be relevant to the students and also focused this on their major disciplines [4, 6]. They provided a Python course delivered using blended-learning approach that covers a large amount of their learning outcomes. There has been increasing demand for computer science modules from non-computer science majors who recognised the significance of computing related discipline in their field of study [2, 13]. We hope our new provision will cover general Computer Science skills needed by non-majors in their future careers. We offer modules that are suitable to all registered students with no experience needed. We ensure our courses support diversity, equality and inclusion in computer science that will encourage community and motivate interest among the students regardless of their major discipline [4].

6 WHAT WILL YOU DO NEXT?

A number of actions are planned to identify which elements of recruitment, and the early weeks of the course, were positive or negative and feed them back into our plans for the next academic year. In the short term, we wish to understand why students did or did not take our minor, with particular attention to their demographics and attitudes. We intend a short, 3–4 question survey to the entire year one population to identify the common reasons for selecting a different minor programme and investigate if any correlate with their demographics. Students also have the option to change minor within the first three weeks of term; we intend to have a short face-to-face interview with such leavers to explore the reasons (currently only a single student). The outcomes from these two actions will be known by the end of the term and can be used to inform changes to the recruitment strategy in time for activities targeting incoming 2020 students. We also intend to follow the students who have taken the minor through the entire programme and the rest of their degrees. During term one, they are being asked to complete a questionnaire on their background, attitudes, and perception of Computer Science and technology. A shorter version of this will be given to them at the start of term 2, the end of the course, then at the end of years two and three of their major degree. This will track any changes in their attitudes

once they go back to solely studying their major and applying (or not) what they have learned in the minor to it, addressing our key goal of practical skills being transferable back to their major study. Questions will also target if digital skills were raised in internships and interviews, and students responses to that. We also intend to collect experiences and quotes from students during the course to use as stories targeted to students within the same major during the next recruitment cycle. This will help directly address identity issues by showing the experiences of real individuals from the same major. Based on the experience of face-to-face recruitment in the queue at the minor event, we believe this personalised connection will more effectively help them imagine themselves in the minor.

After the initial three week computational thinking module, students take a six week introduction to programming. This makes heavy use of blended learning by having large numbers of small videos on individual topics, slides, programming tasks, and formative progress quizzes, as well as the weekly face-to-face studio sessions with staff. The intention is to both allow the students agency to vary the exact order in which they cover the content (to help maintain their interest), and also to illustrate the interconnections of programming concepts. We log the students' interactions with the online blended materials to examine this. Part of the studio sessions involve staff asking each student about their study over the previous week. We can compare this with the logs to use as a ground-truth to identify what patterns do/do not correlate to a given situation (e.g., good engagement with the quizzes but zero engagement with the videos might indicate disinterest or just watching them in a study group on another persons computer). These will then be used as hypothesises in the next iteration of the module to discover if they have predictive power.

7 WHY ARE YOU TELLING US THIS?

Digital skills are vital across almost the entire range of academic disciplines. The national push within primary and secondary education to increase digital skills and specialise from ICT to CS needs to continue into tertiary education. At this point in time, many institutions are experimenting in doing so using a number of different models. It's therefore the correct time to be sharing experiences in order to refine what is a relatively new kind of offering.

If the aim of such courses is to leave students with independently applicable, transferable skills then we need to explore the entire range of possible provisions to identify which is most effective. The first two steps to enable this are the design of the course via its teaching and learning approach, and effective methods of attracting a diversity of students into the course. We have given our rational and first experiences of these two areas to further discussion on how to accomplish these goals.

As detailed above, the pervasive nature of new technologies and the associated digital skills shortage has seen a national push across all stages of education to increase educational exposure to such technologies and skills. However, as our own data and HESA data testifies, Computer Science struggles to attract a diverse intake of students. This is due to many varied and complex factors, but has a deep and wide ranging impact on society with recent research addressing the impact of diversity on factors such as productivity, creativity, financial performance, bias in decision making and bias in product design. Our programme aims to address this lack of diversity through opening up significant elements of creative and applied computing to all first year undergraduates, irrespective of their choice of major discipline, and with no previous experience necessary. The overarching design paradigm that we have followed (see Table 1), and the associated good practice guidelines for inclusive curricula [7] have been embedded in the design of our programme. We've taken care to consider the use of space and re-designed our studios to encourage a collaborative mindset. The recruitment figures show a significant improvement in gender diversity (39.1% females – compared to 14.9% for our 'normal' Computer Science degrees). Furthermore, academic diversity is improved, with students coming from a range of backgrounds including mathematics, geography, management science, environmental science, chemistry, design, psychology, linguistics, and philosophy. Whilst we are still in the early stages of this programme, we believe that a year-long, credit-bearing, Computer Science-based programme will empower students with the necessary digital knowledge and skills to make a positive impact on their major subject, their future careers and on society.

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