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Second level computer science: The Irish K-12 journey begins

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ABSTRACT

This paper initially describes the introduction of a new computer science subject for the Irish leaving certificate course. This is comparable to US high school exit exams (AP computer science principals) or the UK A level computer science. In doing so the authors wish to raise international awareness of the new subject's structure and content. Second, this paper presents the current work of the authors, consisting of early initiatives to try and give the new subject the highest chances of success. The initiatives consist of two facets: The first is the delivery of two-hour computing camps at second level schools (to address stereotypes and provide insight on what computer science really is), which was delivered to 2,943 students, in 95 schools between September 2017 and June 2018. Second, the authors followed this with teacher continual professional development (CPD) sessions, totalling 22, to just over 500 teachers. Early findings are presented, showing potentially concerning trends for gender diversity and CPD development. A call is then raised, to the international computer science education community for wisdom and suggestions that the community may have developed from prior experience. This is to obtain feedback and recommendations for the new subject and the authors' current initiatives, to address early concerns and help develop the initiatives further.

CCS CONCEPTS

• **Social and professional topics** → **Computer science education**; **CS1**;

KEYWORDS

Computer Science Education; K-12; High School; AP Computer Science, Introduction to Computer Science; Curriculum

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1 INTRODUCTION

Organised Computer Science Education (CSEd) at Junior Cycle (similar to the GCSE in the UK or 8th grade in the US, where ages typically range from 12 - 16) or Leaving Certificate (similar to A levels in the UK or AP or SATs in the US, where ages typically range from 16 - 19) has been a long road to implementation in Ireland. This falls under K-12, a term used to describe education grades from kindergarten (pre-school or initial school entry) up to but not including college / third level. CESI [8] (Computers in Education Society of Ireland), who are the longest standing CSEd community body in Ireland and have recently been anointed the official teachers representative body for the leaving certificate computer science subject, have been advocating this movement since 1973. On several occasions CESI have been close, but each time have failed (not without effort and drive) to get CSEd accepted as a formal subject in our second level education system. CESI are not the only group advocating for CSEd at second level. Over the past number of years Lero (Irish software engineering research centre) and the CoderDojo [10] clubs (which was started by a second level student in Ireland) to name but a few, have fuelled the movement for introducing formal curricula. CoderDojo has well over 200 clubs across Ireland and has now reached 65 counties [11]. Despite this and the well acknowledged fact that Ireland is a strong player in global IT, up until 2016 even basic computing curricula were not developed into formal education. Compounding this was the ongoing concern about the inability to fill the jobs void currently in the market [16, 30].

Anecdotally, the authors have also identified and acknowledged the outstanding but disparate that work that has been championed by second-level teachers. In this space, teachers who are not qualified in CSEd or have limited exposure themselves to formal computer science education (or have completed just basic coding courses) have been on the ground trying to develop content themselves. This has in some cases wiggled its way into parts of the

current curricula, that are not perhaps formally assessed, for example general IT classes. This is both positive and concerning. While organisations like CESI try to build relationships between these amazing teachers, the methodology can sometimes be significantly different to the teacher in the next school. This shortfall of coherent approaches and content is not an ideal situation. Compounding this, with the competitive pressures at third level institutions for funding, etc., institutions who are supporting CPD (continual professional development) to teachers, themselves can differ in methodology and content. It is rare to find multiple institutions communicating or even working together in an organised capacity, and this is outlined in a governmental STEM report which presents only a single collaboration [30] between academic institutions. While it is acknowledged that some informal arrangements may exist, this is concerning. It resonates, as previously mentioned with teachers, if no communication is developed, different institutions may be promoting varying and possibly contradicting pedagogical or methodological practices and advice to budding computer science teachers.

2 COMPUTER SCIENCE SUBJECTS IN IRELAND

This section presents the two curricula that have been developed in recent years (2016 on) which are currently being rolled out in pilot form (phase one). Although the focus of this paper is on the Leaving Certificate computer science subject (presented in section 2.2), it is worth mentioning the Junior Cycle coding curricula, as this may be a path taken by students prior to entering the Leaving Certificate subject.

2.1 Junior Cycle Short Course - Coding

The initial offering from the NCCA (National Council for Curriculum and Assessment) came in the form of a Junior Cycle Short Course, introduced in ~2016 [15] . The Junior Cycle covers the first three years of secondary school. Children begin their second-level education around the age of 12 or 13. The Junior Cycle examination is held at the end of the Junior Cycle in post-primary schools and students normally sit the exam at the age of 15 or 16 [9]. A Junior Cycle short course is a 100-hour course and can be delivered at varying stages across the three years of the Junior Cycle. They are classroom-based and assessed, with an emphasis on active learning. The short courses were not intended to replace existing subjects, but allow schools to broaden the range of learning experiences for students, and to access areas of learning not covered by the combination of curricular subjects available in the school. An author was briefly involved at the final forum for the specification in 2014.

This course has three strands. The first of which is "computer science introduction". This has grounded links for computer science comprehension and the understanding of a notional machine. The second strand is titled "lets get connected". This strand develops communication and architecture comprehension with a related learning outcome (LO) to build a website using HMTL and CSS. The final strand and perhaps the core, is "coding at the next level". It is noteworthy that this strand covers procedural and parallel or sequential program flow and identifies a LO using linear data structures (such as arrays). From interactions with the NCCA and being present at the final forum, it was envisioned that the language selected would be block-based and perhaps only text-based (such as Python) if the teacher felt it appropriate. This curricula is still in its initial phases of roll-out.

2.2 Leaving Certificate Computer Science

In February of 2017 it was announced that a leaving certificate computer science course was to be fast-tracked for roll-out of its initial phase one (schools n = 40), to be ready by September 2018. This was unheard of in terms of a curriculum development time-line. For comparison to other jurisdictions the complete Irish on-line curriculum and resources can be found at [20]. This fast-paced development has perhaps led to significant content differences and approaches to that of similar courses in countries like the US and the UK (for example the applied learning task: programming embedded systems, discussed further in this section). Durig this process, the NCCA commissioned a study of computer science second level education in other jurisdictions to inform the Irish process [7].

The call for phase one schools (also known in other jurisdictions as pilot schools), had a very positive interest (schools n $\approx$ 140). The course structure for assessment consists of a 70% terminal examination (with discussion that it would be online) and a 30% mark for a practical project based on one or more of the applied learning tasks as detailed in the course specification [22]. The NCCA have also specified two programming languages that the course must only use, Python and/or JavaScript. The main rationale is, as the state exams commission (SEC) grade the terminal exam centrally, a multitude of programming languages may be difficult to regulate or get teachers to grade. Similar to the Junior Cycle Short Course, the Leaving Certificate Course consists of three strands. Strand one is "practices and principles", strand two is "core concepts" and strand three is "computer science in practice", which in essence compliments strand one and two [22].

Strand One: Practices and Principles

This strand focuses on the problem solving process in a context-based approach related to social, professional and scientific contexts. There is a focus on studying the role of computers in society to enhance students' attitudes towards computer science, in the hope of making it more tangible and meaningful. The strand's subheadings are: computational thinking, computers and society (which incorporates ethics, machine learning and artificial intelligence) and design and developing.

Strand Two: Core Concepts

This strand is more content focused, highlighting programming (as mentioned, in Python or JavaScript). The topics in strand two are: abstraction, algorithms, computer systems, data and evaluation and testing. The specific content is very detailed and some very specific learning outcomes stand out: for example, unit testing. While the programming is comparable to the UK A Levels [14] and the US AP Computer Science Principals [12], it is not as in depth as the US Computer Science A [31], (although it is argued that Computer Science A is a software development course, and does not broaden).

Strand Three: Computer Science in Practice
Strand three consists of four applied learning tasks (ALTs), with the aims and objectives of creating artifacts that link strand one and two. Applied learning task one is "Interactive Information Systems". This consists of the development of an interactive website that can display information from a database (at higher level, a relational database) while understanding user requirements. This is regraded as one of the more difficult ALTs, as students will need to master databases and web development (HTML and CSS) and link them all together. ALT two is "Analytics". This requires students to obtain raw data and perform tasks such as pre-processing, basic statistical analysis and communicate the results in graphical form. ALT three is "Modelling and Simulation". This will require students to model different scenarios and interpret simulations, while also understanding agent based modelling. Finally, ALT four is "Embedded Systems". This ALT requires students to use a microprocessor system such as the Arduino, Raspberry PI or BBC Micro:bit to name but a few. Students will need to control inputs and outputs to the system, including analog signals.
The NCCA have presented the structure of the course in Figure 1. This is to illustrate how the ALTs compliment "Practices and Principals" and "Core Concepts".

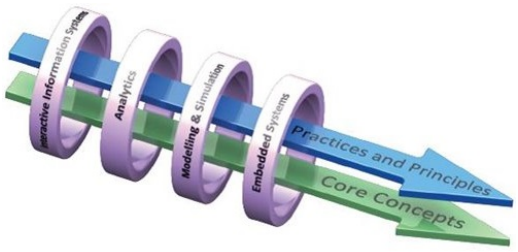

Figure 1: The structure of the three strands of the leaving certificate computer science subject, [22].

Although none of the authors were part of the initial development group, some authors have worked with the NCCA since, in furthering the curricula. One example of this was the development of resources for the teachers. This included scaffolding video tutorials on the Micro:bit [21] and Python scaffolding video tutorials to compliment strand two [23]. Another author is the external expert on the Department of Education and Skills subgroup on teacher training, working with representatives from the NCCA and other stakeholders.

3 MOTIVATION

The authors' overarching motivation for this work is to develop a multi-institutional collaboration group, to contribute to and help ensure the success of the new computer science subject. The authors are also from three different Irish institutions and believe that is this the first collaboration of its type where third-level lecturers and researchers have collaborated to help Ireland's national CSEd goals. This is a new subject thus any initiatives or contributions that the authors can assist in or develop is the group's primary focus. The authors believe that this is vital as there are concerns with single institutions or educators embarking on such work in silos, as sometimes (without fault of the educator), any single or small number of individuals may not have the combined experience or net of review prior to intervention deployment. Such a situation could not only have no effect, but could have negative effects on the larger community. This collaboration group has several goals:

3.1 Goals

(1) Work together (including peer review), to develop clear and coherent content, resources, workshops and CPD, to primary schools, secondary schools and even to an extent third level.
(2) Conduct longitudinal, multi-school research, to shape future work, while also disseminating the results of this work so that all educators can build upon and contribute to this effort.
(3) Informing students, guidance councillors, educational bodies and school managements to what the new subject consists of, what computer science really is, and most importantly what it is not, by addressing stereotypes and misconceptions (and sometimes mis-information).
(4) Inform third level bodies, academics and researchers to what the subject entails and what to expect from students progressing into third level. This transition from the new LCCS to long-standing third-level CS programs is very important and uncharted territory in Ireland.
(5) Address student and teacher computer science self-efficacy issues which anecdotal evidence suggests are commonplace.
(6) Address diversity, inclusion and gender issues that currently plague CS (particularly as an academic discipline), by focusing on teachers, and the primary and secondary school students they teach.

3.2 Concerns

A primary concern is one that faces almost all western world computer science courses (but it is acknowledged that this is not the case in many Middle Eastern or Asian jurisdictions). That is gender balance, in computer science. As Ireland faces its phase one implementation, it is noted that the 40 schools were selected based on criteria, and it is accepted that gender balance must have been one, based on the final set of schools, many of which are girls schools (not formally acknowledged). However, when the main roll-out commences, and is available to the entire population, there is a concern that the female numbers may drop significantly. This happened in the UK (from the prior ICT A level to the computer science A level course) where 40% female representation dropped to 9.8% in a short period [32]. It should be noted that in the US, AP computer science principals was only examined in 2017, which even with promotion only had a female representation of 26% [4]. This is compounded by college figures where in Ireland the gender balance is $\approx$ 20% and where computer science has the highest third level first year and first to fourth year attrition rates [17, 19]. The authors are concerned that second level may follow this trend.

3.3 Foundations for Future Work

Although initial work has begun (Section 4), the following literature will play a fundamental role in shaping future work. This is by no means exhaustive but highlights some of the areas that the authors will focus on. There has been a significant amount of work on

methodologies and factors that could address some of the concerns or aid in diversity, stereotypes or attrition rates. Some of these studies include introductory programming research [2, 3, 6, 18], factors that influence success in introductory programming courses [5, 24, 25, 27, 28], interventions in CS1 [26] and finally gender differences in CS1 [29]. Future work will include further analysis and investigations of this literature.

4 INITIAL WORK

Two of the authors have previously worked for / with the NCCA. One author developed a significant amount of resources for the Python programming and the ALT4, using BBC micro:bit. The micro:bit has had a very positive influence in the UK [1]. The authors have also been involved in school computing camps. This year they offered free camps to schools (sponsored my Microsoft Ireland). This allowed the team to travel to schools. This aimed to address goals 1, 3, 5 and 6 (Section 3). A short course was developed that consisted of an introduction to computer science (to address stereotypes), introduction to coding using the micro:bit, and finishing with Bebras computational thinking questions [13]. This two-hour computing camp received strong positive feedback. In fact with word of mouth, minor promotion and the camps being in their inaugural year, 95 schools participated. Informal feedback from teachers was extremely positive and students were more or less insisting on follow up sessions. In a large proportion of schools the visits consisted of several camps, with different classes participating. Some days, 3 sessions of up to 30 students each were conducted. Over the 2017-18 academic year the team delivered these camps to 2,943 students throughout the country.

The authors acknowledge that one-shot interventions have their limitations and some would argue that they may even have a negative effect, as the following week the teacher may not be able to continue with the content as they may not have the domain knowledge or skills to do so. Thus the second phase of our initial work commenced: CPD to support teachers to allow them to continue with the methodology and content. In total 22 CPD workshops were run to support teachers, from Python (introductory, intermediate and advanced), BBC micro:bit (introductory and advanced) and even CPD on "what is coding" to educational boards. In total the group supported 503 teachers with CPD (including some repeated sessions).

This initial work has shown the energy and enthusiasm that many teachers have; some sessions were on weekends, and although the sessions were free, teachers did not receive any remuneration or official 'credit' for their participation. This demonstrates that teachers want to up-skill and be able to deliver this course, and this energy has been the catalyst to develop this research group and to address the goals as outlined in Section 3.

5 EARLY FINDINGS

The initial work was conducted to try and positively influence students and their perceptions of computer science, and not specifically the leaving certificate course, nor was it intended to be the catalyst for a larger body of effort or research.

An overall positive finding, was the gender balance that the camps and CPD were able to achieve, as presented in Figure 2. This shows a ratio of 56% male and 44% female. Please note that gender numbers were only recorded in the last quarter of the academic year, *n = 1,329*. Thus, future work as outlined in Section 7, will build upon these early findings and record many more attributes for the camps and CPD now that ethical approval has been granted. It is also worth noting that the schools and teachers were not pre-selected, but those who opted to contact us or attend the sessions. It will be considered very positive if a similar ratio of students is reflected in official uptake of the new subject.

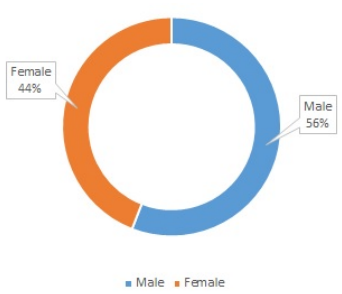

Figure 2: Overall breakdown of gender in computing camps and teacher CPD, *n = 1329*.

Unfortunately, while the next two findings start very positively, they show concerning trends. For teacher participation in CPD events, the micro:bit introduction showed the ratio of male to female teachers was 60:40 (inner loop, Figure 3), but the ratio of male to female teachers in advanced micro:bit was 78:22 (outer loop, Figure 3). A similar trend was observed for the Python CPD events, as shown in Figure 4. In the introductory Python CPD, female teachers outnumbered male teachers, but as the CPD increased in difficulty, the trend reversed. The authors anecdotally believe from feedback during the CPD, that this may not be attributed to competency or qualifications in the subject, but possibly self-efficacy. This will be investigated in more detail in future offerings.

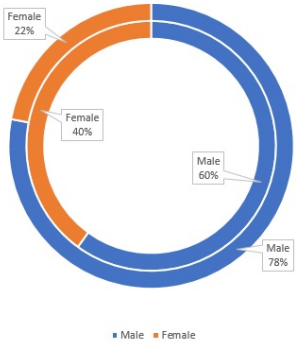

Figure 3: Teacher CPD, male and female participation for an introduction (inner) and advanced micro:bit (outer).

6 A CALL TO THE CSED COMMUNITY

The authors would like to issue a call to the CSEd community. They invite any wisdom, experiences and suggestions, based on prior experience of introducing a second level computer science subject. This is to obtain feedback and recommendations about the new

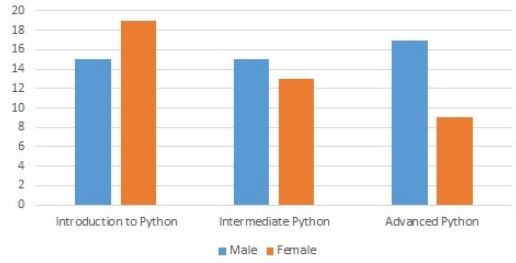

Figure 4: Teacher CPD participation by gender for three progressing Python workshops.

subject and the authors current initiatives, to address early concerns and help develop the initiatives further. We would also call to open up further dialogue and collaboration with other institutions and individuals, in Ireland and globally, to try and insure every possible success for the subject.

7 FUTURE WORK & DIRECTION

School and teacher feedback for this series of work has been overwhelmingly positive and a significant number of schools have since volunteered to participate in future research. The authors also believe that teachers realize the additional value that research can bring to this space, as evidenced by the enthusiasm and energy that is present at the moment in second level computer science education. On that note the authors have applied for ethical approval to run detailed studies with as many schools and teachers as possible in the 2018-19 academic year. The study details and contents are currently being finalized with questions and methodologies developed from the authors' experience and the literature presented Sections 3.2 & 3.3.

The authors hope to continue working with the NCCA, and other institutions, not only to develop more coherent, peer reviewed content and methodologies but also to inform educators (from non-specialists in second level education to third level academics) to ensure that everyone has similar non-stereotypical views of computer science with as little misconception as possible. This is all, most broadly, in an effort to positively contribute as much as possible to the success of Computer Science as an official subject in Irish secondary schools. It is hoped that, perhaps as a by-product, improved uptake in CS at third level will result.

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