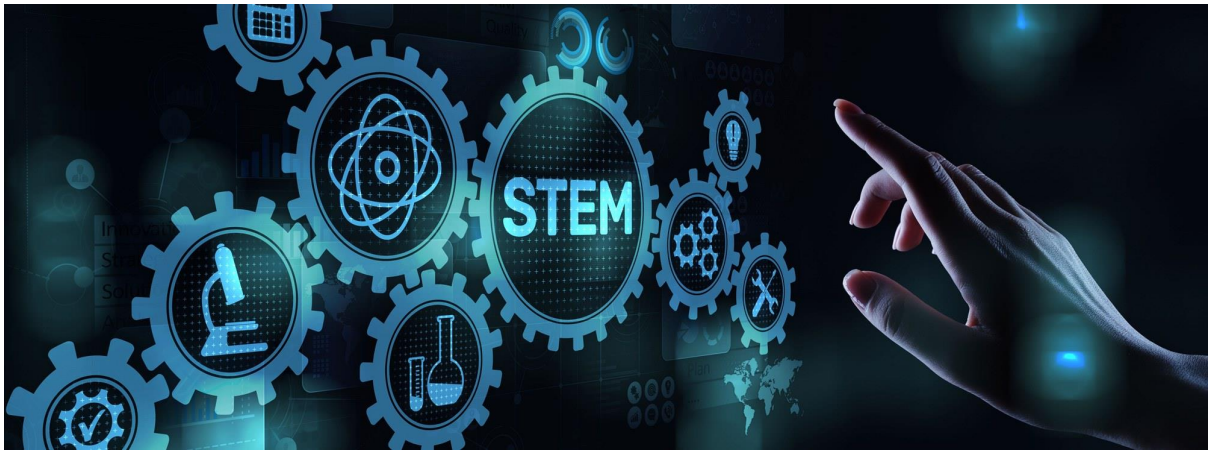

Addressing Uptake and Gender Balance in Computer Science: The Success of CSinc

1 - Karen Nolan

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Ireland is a strong player in the global IT industry but there is an ongoing concern among employers in the sector about the inability to fill related jobs in the market (FIT, 2018; L&RS, 2017). Falling numbers pursuing Computer Science in Higher Education and a low female uptake of the subject compound the labour market challenge. Computer Science as a third level subject suffers from a litany of significant obstacles. One is that female students comprise a maximum of 20% of participants. This is disconcerting for educators, as female students out-perform their male counterparts in the discipline (Quille et al, 2017). In addition, the student attrition rate in Computer Science is the highest of any third level discipline (Mooney et al, 2010; Liston et al, 2016). All of this may present a negative perception of Computer Science to students who might otherwise consider taking the subject at third-level. These perceptions are formed between late primary and early secondary education. Breaking down these barriers and misconceptions is the mission of the Computer Science Inclusive (CSinc) research group, of which I am a member. Founded in 2017, CSinc consists of four computer science lecturers - Roisin Faherty, Karen Nolan, Keith Nolan and Keith Quille – who devote their spare time to promoting inclusivity and inclusive practices in Computer Science at primary and second-level.

Research has shown that pre-university students and their parents have an incorrect perception of the field. One of the top reasons why students with an apparent aptitude for Computer Science did not consider it as a future subject choice was their lack of desire to sit in front of a computer all day (Carter, 2006). Gender stereotypes (e.g. computer science is for boys) and cultural expectations (e.g. parents' discouragement) were also significant factors that could influence the decisions of females not to study Computer Science (Alshahrani et al., 2018). The goal of our work in CSinc is to try and address these concerns.

Enabling students to take Computer Science in second level has been shown to lead to more students choosing the subject in higher education (Armoni, 2014). While many third-level institutions are developing outreach models, the format, methodology, and pedagogical approach differs significantly between these models. CSinc focuses on the development of an inclusive outreach model that lends itself to longitudinal evaluation, as it incorporates a large number of schools and varying student profiles. If proven, this model would be a valuable contribution to the community where we could positively influence students' perceptions and identify with more precision where in the pipeline students fall away.

The programme is available at no cost to any interested school in Ireland.

As part of this work, CSinc currently run three separate student outreach programs, each with different criteria, in an effort to promote Computer Science nationally, which are completely free for the students and their school. These are:

- **A general introductory outreach programme which aims to address negative perceptions of the subject.** Pedagogies are developed to demonstrate what Computer Science really is and more importantly what it is not; and to highlight the skills needed for the domain. This outreach programme is aimed at students who have never experienced a formal Computer Science class and range in level from 3rd and 4th class in primary school up to Leaving Certificate (Nolan et al, 2020). It has been delivered to over 10,000 students to date.
- **A specific Transition Year (TY) Computer Science Programme,** providing a scaffolded MOOC (Massive Open Online Course) to enable schools that may not have the facilities, resources, equipment or qualified teachers to deliver formal Computer Science curricula, to access a collection of eight week mini-courses. This is currently piloting in over 50 schools and to 2700 students.
- **A Leaving Certificate Computer Science (LCCS) set of outreach camps**. This new LCCS subject is in its third year of a national roll-out (Quille et al, 2018). The CSinc outreach consists of workshops targeting specific components of the Leaving Certificate subject specification. Since going virtual with these camps in October 2020 we have had a total of 478 students, from 30 schools attend sessions (by end of January 2021).

To compliment all of the above CSinc also provide additional teacher CPD workshops (~40 per academic year), building teachers' capacity to run and develop Computer Science courses in

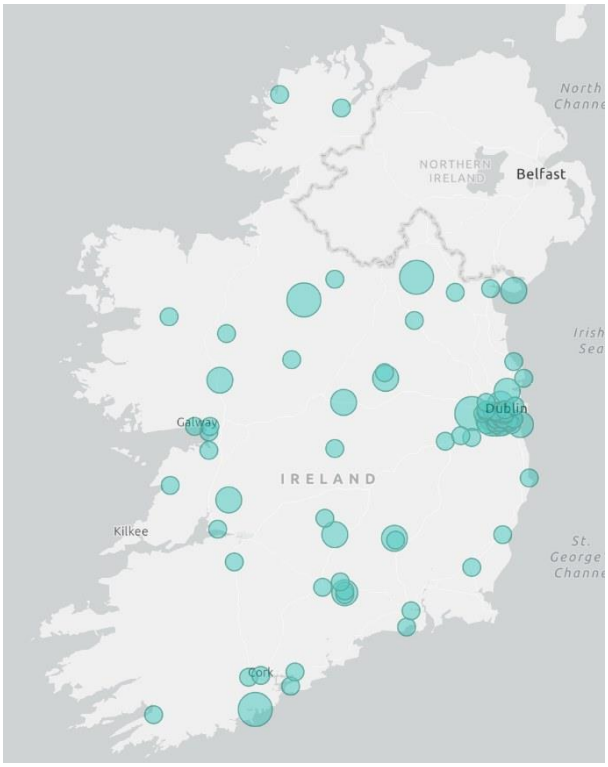
their schools. 130 teachers have attended our CPD in the last 10 months, and each teacher attended on average 3 or more sessions.

The longest running of the above outreach programs is the introductory one aimed to address negative perceptions of the discipline and demonstrate the skills needed for the domain. This program is open to all primary and secondary schools across Ireland. Booking for the programme is on a first come first served basis and information regarding the programme is disseminated through our social media advertising and our email list. The camp incorporates on-site school delivery (one of the four volunteers travels to the school, no matter where in Ireland it is located). The programme is available at no cost to any interested school in Ireland.

2 - Figure 1: CSinc Camp Visit Pictures

3 - Figure 2

Over the last three academic years, the four CSinc volunteer members have worked with over 100 schools and approximately 3300 students per year (Figure 1 and Figure 2). Overall, we have engaged with students from every county in Ireland. This amounts to about 40 hours of volunteer outreach per week (Figure 2).



4 - Figure 3: CSINC Camp Visit Locations Ireland 2019-2020 Academic Year

The camp structure is divided into three sections:

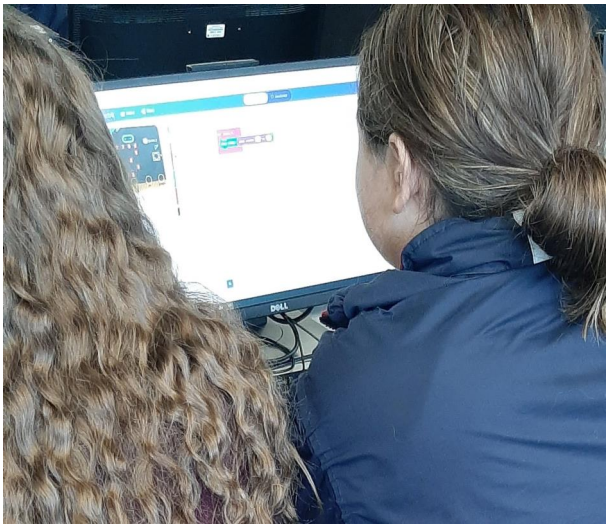
1. Introduction to the roles and careers of a computer scientist

5 - Figure 4

This session is short and interactive, typically consisting of a 15–20-minute presentation using visual aids. Initially stereotypical images are shown, and the students are asked what they think could be wrong with each image. (as demonstrated in figure 4). Identifying stereotypes in the images uses a think-pair-share approach (Kaddoura, 2013) to encourage critical thinking and group discussion. This guides students to uncover what was missing from the stereotype images, such as working in groups/teams or female computer scientists. Following this discussion, a presentation on the work-related roles and environments available to computer scientists is given.

2. Hands on coding (using micro:bit)

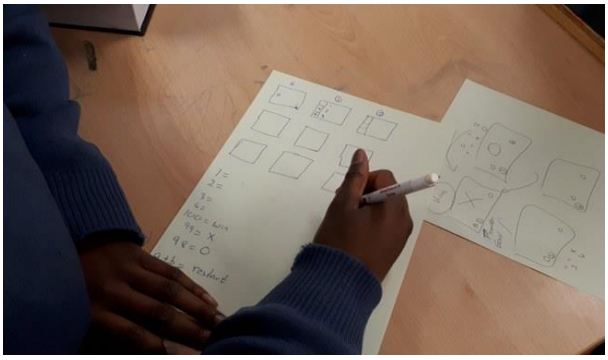
The introduction is followed by a hands-on coding session. Many schools do not have sufficient funding to have well maintained functional computer labs and where they do the labs are not always available for use. To alleviate this, dedicated laptops and tablets were purchased for this project to allow the team to visit schools and use regular classrooms to run the camps. The integrated development environment (IDE) chosen was the MakeCode online IDE. This IDE allows programs to be cached and the outreach camp can run even if there is no WiFi available. The IDE uses block-based programming, similar to that of Scratch. The coding session involves activities with increasing levels of difficulty: starting with displaying the student's initials on the screen up to and including building and testing a step-counter. Activities used include Modelling; PRIMM (Sentance, 2019); Targeted Programming Tasks (Debugging, Intentional Errors, Fill in the gaps, Worked Examples); Narratives; Paired Programming; and Algorithm Design.



6 - Figure 5: Hands-on coding.

3. Hands on problem solving (using the Bebras challenge)

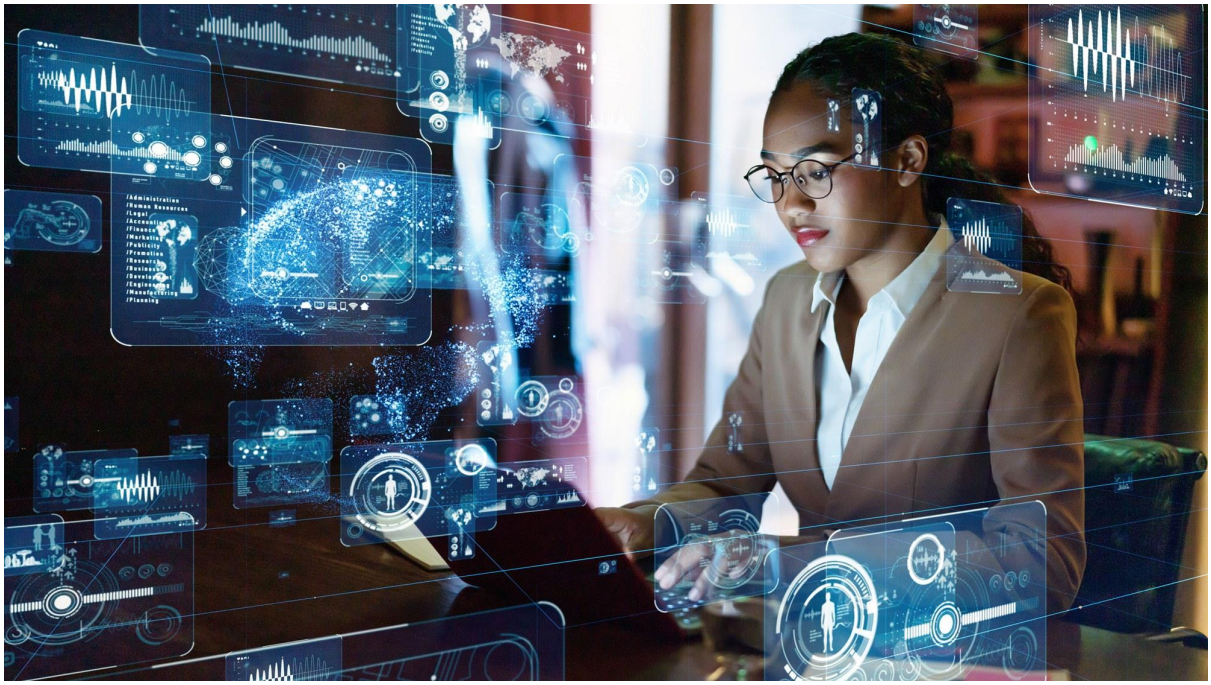
Finally, in the last 30 minutes of the outreach session, the students participate in pen and paper activities using problems predominantly sourced from the Bebras challenge, with some additional problems sourced from third level. The additional problems aim to provide differentiation if required for strong students who may be at risk of getting bored with the typical challenges. In this session, students typically attempt four to ten questions, depending on the group and level. After each problem is attempted, it is decomposed and discussed. Activities used include Algorithm Design; Representation; Computational Thinking; and Abstraction.



7 - Figure 6: Hands-on problem solving

While these educational goals are not new, we believe that what is novel is the development of this model, with underlying research and validation using a large-scale longitudinal study. The three sections of the general introductory outreach camp have been structured using widely acknowledged pedagogical approaches where possible, and pilot pedagogy approaches where not, with the aim to examine them over time. More information on the programme can be found in the literature (Nolan et al, 2020).

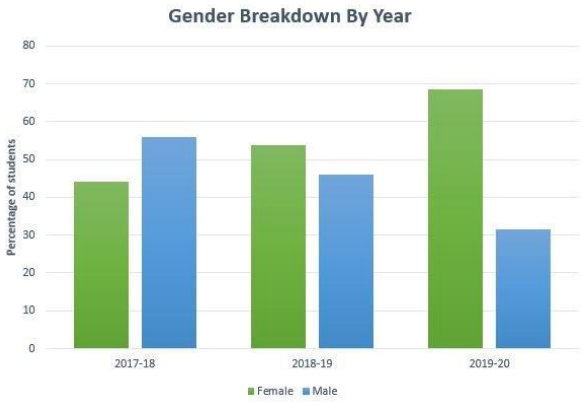
Findings



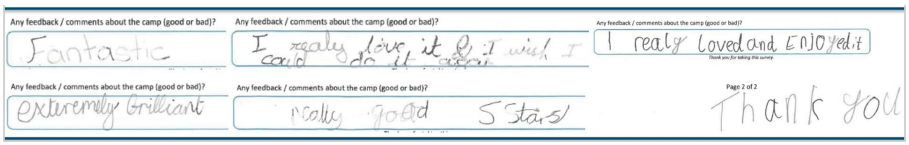
The findings from the general introductory outreach programme are very positive, particularly with regards to the balance of male and female participants. In the 2017-18 academic year it was 56:44 (male:female) and by 2019-20, it was 35:65 (male:female). Schools self-select, thus we are not targeting specific female or DEIS schools, perhaps highlighting the effect of our outreach development. The shift in gender balance towards

greater female participation also signals the interest of schools, and female pupils, in becoming familiar with Computer Science when the opportunity is offered to them. In addition, with the popularity of the camps (this year they booked out in three days) CSinc has also run outreach camps with PLC centres, VTOS, Foróige and the Midlands Prison Service.

Figure 7 shows the trend of female uptake. We argue (and hope to confirm when the data has been analysed) that this is attributable to the pedagogical development over the three years. As one primary school student said, "I really love it and I wish I could do it again". Similar positive feedback from students can be seen in Figure 8:



8 - Figure 7: Breakdown of Male and Female Participants in the CSINC Outreach Camps



9 - Figure 8: Some feedback from students

In addition, several higher education institutions are seeking to use our model, and our plan this year (2021) is to openly publish it so that other institutions can use it locally. Our model will include an out of the box booking system, local school contacts list and an automated (validated) student survey process. This year three institutes have agreed provisionally to use the model, based on the positive findings, to further share and run locally and help address inclusion and the negative perceptions in Computer Science nationally.

While we are only in year three, initial indicators are quite positive. One of the key objectives of the camps is to increase the participation of students in Computer Science and to improve the gender balance. We are encouraged by the fact that over 66% of students taking part last year were female. If this research can provide insights into underlying factors that improved female uptake, this may positively impact on discipline uptake in third level, and in turn address the shortage of skilled graduates for industry. Anecdotally from direct

feedback during the outreach visits, we have received positive responses and claims of changes in perception. Enrolment of females has increased in TU Dublin Computer Science undergraduate programmes by 35% since 2015 (TU Dublin, 2020) and we are hopeful that further analysis will demonstrate that CSinc might have helped to play a role in this increase. With the rollout of this model to three further HEI's and its continued rollout in TU Dublin we hope to build on our successes thus far.

Karen Nolan is a lecturer of Computing in the Technological University Dublin (MSc, and PhD Candidate). Karen is an experienced Software Developer, having previously worked in Industry for 15 years. Karen now uses this knowledge to teach a wide range of modules, including Software Development, Software Quality & Testing, Software Design, Agile Methods and a number of DevOps modules. Karen's current PhD research focuses on developing primary-and secondary-level Computer Science outreach models. She is also a member of the PDST (Professional Development Service for Teachers) associate team for the Leaving Certificate Computer Science (LCCS) subject and is a chapter author of "HTML and JavaScript", on the book for the subject.

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