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Prior Programming Experience of Undergraduate Computing and Engineering Students in Ireland

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Abstract. Historically programming has not been a subject studied at 2nd level in Ireland, and degree programmes in Irish 3rd level institutions have taken a 'From-scratch' approach to the teaching of programming. It has become apparent that increasing numbers of students arriving into undergraduate computing and engineering degree programmes in Irish 3rd-level institutions have prior experience of computer programming, and the situation regarding the teaching of programming in the Irish School system is currently changing.

Synonyms: Computer science education · Programming experience·CS1

1 Introduction

This article describes the current state of programming experience of Irish undergraduate students on entry to 3rd level, exploring it's sources and impact and presenting some comparative international context.

1.1 Irish School System

What follows is a brief overview of the structure of the Irish school system in order to provide a context for the following discussion. The Irish school system is made up of primary, and second-level education. Primary education consists of an eight year cycle: junior infants, senior infants, and first to sixth classes. Pupils normally transfer to second-level education at the age of twelve. Second-level education begins with a three-year junior cycle after which students take the Junior Certificate examination. This is followed by a two-year or three-year senior cycle depending on whether an optional Transition Year is taken following the Junior Certificate examination. Transition Year is free from formal examinations and allows students to experience a wide range of educational inputs, including work experience. Following their final two years in the senior cycle, students take the terminal state exam known as the Leaving Certificate.

1.2 Programming opportunities for Irish school students

Historically the standard introductory programming course at 3rd-level in Ireland assumes no prior knowledge of programming, as it has not been taught as part a formal subject in the Irish school system. Although a module in Computer Studies was made available in the 1980s as an optional component of the Mathematics Leaving Certificate subject it lacked a clear syllabus and nationally uptake was low. Limited resourcing due to the prevailing economic conditions in the 1980s and early 1990s together with a lack of a clear national policy restricted the ability of schools to develop the teaching of programming.

However this situation is currently evolving, largely in response to industry demands in the face of a perceived skills gap. This is in line with an international resurgence of Computer Science education in schools. In 2014 an optional short course in Coding was introduced which can be taken during the junior cycle of second-level schooling[1] and Computer Science is being introduced as an optional Leaving Certificate subject in September 2018 [3] Furthermore, the National Council for Curriculum and Assessment (NCCA) is actively considering approaches to introducing the teaching of programming to all students in primary schools through its *Coding in Primary Schools Initiative*

(https://www.ncca.ie/en/primary/primary-developments/coding-in-primary-schools). It is clear that 3rd-level institutions will need to adapt to cater for this new generation of students with prior programming experience.

In addition, outside of formal educational settings, recent years have seen a surge of interest in learning to program as evidenced by the phenomenal success of the CoderDojo network of after-school programming clubs. Since its foundation in 2011 the CoderDojo network has grown exponentially to include over 200 clubs across Ireland in January 2017[2], and the academic community in Ireland has become aware that many students arriving at 3rd-level to commence computer science and engineering degree programmes already do so with some prior exposure to programming.

2 Prior programming experience of 3rd level students

2.1 Overview

A repeated cross-sectional study using an annual survey of 3rd level students is currently underway in Ireland [16]. It provides empirical data on what programming knowledge and experience students have before commencing undergraduate degree programmes with a programming component in Irish 3rd-level institutions and explores how this exposure affects their experience of programming during their freshman year. Data from the 2015/16 and 2016/17 academic years of this survey give a view of the Irish student experience and are suggestive of emerging changes. The survey population is freshman students undertaking a third level, undergraduate degree programme in Ireland which involves the studying of programming in first year. Such programmes are typically computer science and engineering programmes. Students are targeted in the latter part of the second semester of their freshman year so they can make a judgement with regard to the impact of their prior experience on their current studies.

While the overwhelming majority of the survey population would have undergone their second-level education in Ireland, it should be noted that as of the 2014/2015 academic year approximately 10% of students in Irish 3rd-level education are “international” students [14], and a number of these students would have experienced some level of formal exposure to programming in their previous education.

From 2016, invitations were issued to 3rd-level institutions nationwide with 8 institutions agreeing to circulate the survey to freshman students. This resulted in a sample of n=321 respondents. The survey collects demographic data such as 3rd-level institution attended, age, gender, and degree programme. It then asks if respondents have prior experience. For those that do the remaining questions explore the nature of that experience and its impact on their current study of programming. It should be noted that as students self-assess their level of confidence and ability, rather than an objective test being applied, this may introduce some bias, though it is not clear in which direction this may lie.

The early results of this study, while limited in their scope, provide an indication of the current situation as well as a baseline from which to evaluate the inevitable further changes in the Irish student profile.

2.2 Data Validity

The total population size is only available for two thirds of the group surveyed, which precludes calculating confidence for our overall results, a deficit that will be addressed in future surveys. Where accurate information on cohort size is available, from three institutions (n=222, population=651), we calculate a confidence interval of ±5.34, at a confidence level of 95%. Our overall results do not differ significantly from the results obtained (i.e., they lie within the confidence interval reported) when only considering this restricted set of the population, nevertheless we must be cautious in interpreting the overall results as a result of this weakness.

Some respondents chose not to indicate which institution they were attending, making it impossible to include them in these figures; a requirement of the study's ethical approval was that no question be compulsory making such occasional gaps in the data inevitable. Where it has been possible to uniquely infer a student's institution from their stated course of study we have done so.

With respect to other threats to validity, we note that having students self-assess their level of confidence and ability, rather than applying an objective test, may introduce some bias, though it is not clear in which direction this may lie.

2.3 Participants

Some demographic information about the survey participants is laid out in Table 1:

Table 1 - Participant details

Year	Total	Male	Female	Age 18-22	Age 22+
2015 (n=122)	122	72%	28%	92%	8%
2016 (n=321)	321	76%	24%	76%	24%

While only around 25% of respondents are female across both years of the study, this is in fact a slight overrepresentation in the survey as enrolment figures for full-time honours degrees for 2014/2015 for females are a mere 14.9% for computing degrees and 18.1% for Engineering degrees [14]. The reason for the substantial jump in the mature student rate from 2015 to 2016 is unknown.

2.4 Programming Experience

Students were asked to self-report as to their programming experience. Of the 321 students who responded to the 2016 survey, **66%** indicated that they had **no** prior exposure to programming with **34.2%** indicating they had some experience prior to the start of their 3rd-level course. These figures are not significantly different from those of the 2015 survey where **63%**of freshman students (n=120) indicated they had no prior experience.

Students were also asked to self-report their prior level of fluency in programming. The 2016 cohort reported having a much stronger level of fluency than the 2015 respondents (see figure 1 for figures and an explanation of fluency levels).

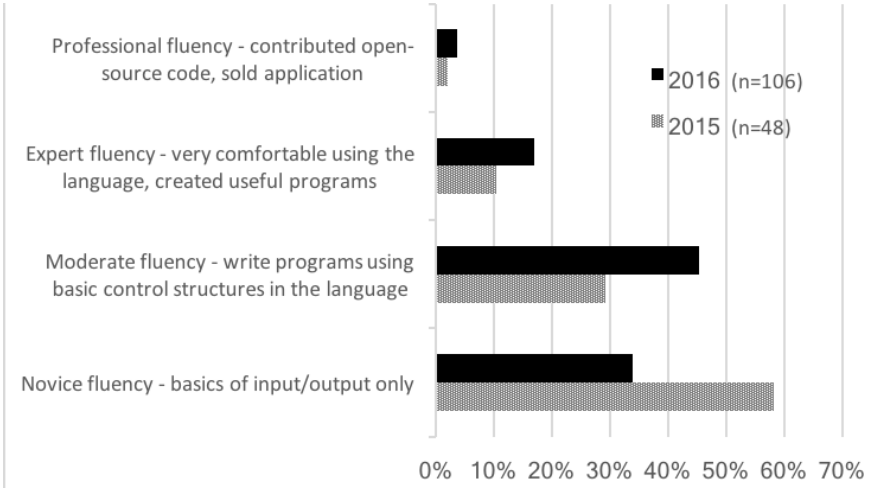

Figure 1 - Level of fluency from 2015 and 2016

The proportion of Irish students reporting programming experience prior to 3rd-level highlights the relatively low level of experience of Irish students have at the outset of their 3rd-level study. This is most likely due to the majority of students coming directly from Irish second-level schools where programming is not yet widely taught. It is notable that the level of fluency reported suggests that for the students who did have experience their previous studies were often deep and considered.

2.5 Programming Languages

Students who reported having some programming experience were then asked to indicate which languages they had some experience with. In 2015 this was presented as a multiple choice list (with an "other" option), while in 2016 students were instead presented with an open question giving respondents freedom to indicate the range of languages they had experienced. The two years' responses are presented in Table 2.

Table 2 - Programming languages experienced prior to 3rd-level

Language	2015 freshmen (n=48)	2016 (n=106)
C, C++, C#	33%	40%
HTML	60%	28%
Java	44%	59%
JavaScript	23%	17%
Other	0%	22%
PHP	0%	12%
Python	25%	33%
Scratch	38%	1%
Basic variants	4%	14%

Students have clearly engaged with a wide variety of languages which is an indicator of the diversity and range of courses on offer. The almost complete absence of the educational language "Scratch" in the 2016 results is likely due to the change in the survey format leading students to omit Scratch from their answers based on a perception of what constitutes a "real" programming language, rather than a reflection of a genuine difference in student experience.

2.6 Helpfulness of Experience

Respondents were asked to report on how (or not) their prior programming experience helped them in their freshman year of studying programming. The question was presented as an open-question prompting a varied response. Interestingly, 15% of respondents in 2015 and 10% in 2016 indicated that their prior experience didn't help at all. The analysis of the responses given by the remaining respondents who did report an impact produced the following broad categories:

- A head start boosted confidence helping students transition to 3rd-level.
- Not struggling with the basic concepts allowed for deeper learning to occur.
- Understanding fundamental concepts helped in adapting to new languages.
- More receptive to understanding complex concepts.
- More time could be spent on studying other modules.

As we might expect, prior exposure to programming concepts is considered helpful when dealing with introductory programming modules. Interestingly, the first group that emerged doesn't relate directly to the conceptual knowledge and skills gained from prior experience but instead focuses on the affective impact of having such knowledge particularly in the area of confidence levels and receptiveness to new learning. This underlines the importance of educators adopting pedagogical approaches that support the growth of confidence in learners. Given the diversity of programming tools and skills encountered, it's perhaps not surprising that familiarity with the core concepts of programming had a significant positive impact.

Since many introductory programming modules focus on trying to impart these core skills, students who have a head start reported that they can focus purely on advanced constructs or even on other modules.

In 2016 only, respondents were asked, again using an open question, which parts of their prior experience were the most useful to them overall. 35% reported that nothing helped them. This could mean that they either didn't find their experience useful or they were unable to articulate or remember any particular aspects they found useful. The remaining respondents' responses were grouped into the categories listed in Figure 2.

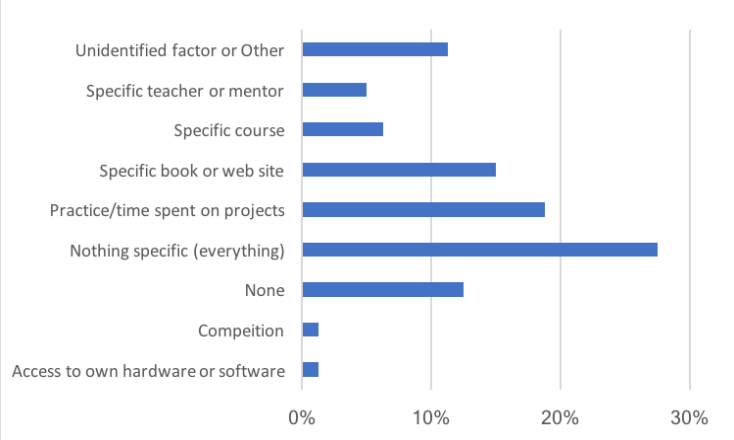

Figure 2 - Sources of Useful Prior Experience - 2016 (n= 80)

Over a quarter of respondents indicated that while their experience was useful, nothing specific stood out as having helped them. With the remaining responses, the most frequently cited helpful activities were time spent on projects or practice (19%) and specific online or print resources (15%) notably Codeacademy and YouTube.

The fact that a substantial number of participants were unwilling (or unable) to identify individual sources of their experience as being helpful could indicate that nothing at all, or no single specific aspect was helpful. However, alternative readings could suggest that students either had difficulty in reflecting on its effect or that their overall experience - rather than specific experiences - was helpful.

2.7 Origins of Experience

In 2016, participants with prior experience were asked a series of questions to gain insight into its origins. These were categorized into school, club, online and self-directed learning with respondents also having an opportunity to indicate any other sources of their experience. This is a particularly interesting question in the Irish context where programming has not been widely available as a formal school subject and grassroots organisations like CoderDojo report considerable activity. Most respondents reported multiple sources for their experience.

School Activities: 27% indicated that they had participated in programming activities through school. These activities were identified as short summer classes, transition year courses (a one year programme in Irish second-level schools with no formal exams prior to beginning the two year terminal examination), elective classes, preparation for programming competitions, and as a formal part of school curriculum (international students). The duration of these activities ranged from 1 day to 2 years.

Club Activities: 13% of respondents reported participation in clubs or groups outside of school. Of those, 36% had attended CoderDojo; 27% were involved with other computer clubs; 19% were involved with 3rd-level access and youth programmes with the remaining 18% citing adult education courses.

Online Activities: Reported participation in online courses (including courses that they may not have finished) was 42%. The most common sites used were Codeacademy (46%), non-specified tutorial sites (27%) and YouTube (7%) with other specified sites each representing just over 2%.

Self-Directed Learning: When asked if they had engaged with any self-directed learning such as books or building projects, 63% answered in the affirmative with the majority of those citing projects that they had designed and developed. These included games (41%), websites (22%), web applications (17%), Arduino/Raspberry Pi projects (17%) and general business applications (3%). The time spent on these projects varied significantly from a couple of hours to a couple of years with the average amount reported as approximately 40 hours.

Other Sources of Experience: 30% of respondents indicated they had other sources of experience. These included post-2nd-level school courses that were not diplomas or degrees (43%), previous 3rd-level courses (23%), previous employment (13%) with the remaining 21% not specified.

When examining the origins of prior experience, it was not unexpected, given the lack of formal inclusion of programming in Irish schools' curricula, that a high number (73%) of respondents gained their experience outside of school. Indeed, what was surprising was the extent and range of extra courses run by some schools both as part of their day-to-day curriculum and as extra short courses after school.

The 13% of students of students who participated in clubs/groups compared to the proportion participating in school based activities (27%) may seem low given the high profile of CoderDojo. However, this may be due to the relative infancy of this club, founded in 2011. This number might be expected to increase in the future in line with the increasing participation and growth of dojos in Ireland. However. It is clear that for students in the survey cohort most non-online computing activities undertaken by students have been via schools.

Not unexpectedly, there is a relatively high number of students undertaking online courses with Codecademy being the clear leader. The most popular languages being learned online are the web development scripting languages and Python.

3 Comparative International Perspective

There is a shortage of comparable national studies to place the Irish situation in full context but some comparisons with international standards can be made. While prior knowledge of programming has generally not been the primary focus of research some studies have investigated the effects of prior knowledge on such things as confidence levels [4], problem solving [5] and gender balance [8] with previous programming experience often being cited as a predictor of programming success [6, 7]. Interestingly, studies have shown that it is not prior knowledge of programming concepts alone but student self-efficacy, or their self-perception of their programming ability that has the strongest correlation with programming

performance [9, 10]. Krpan et al's investigation into the correlation between students' success in introductory programming and mathematical courses included an analysis of student expectations and success rates in introductory programming courses at the Faculty of Science, University of Split over three years. They found that early failure to understand basic programming concepts affects students' confidence and leads to increased drop-out rates [11].

The background of Computer Science freshmen across two Finnish universities, was investigated in 2011 and 2012[12]. Differing levels of prior programming experience were found between the two institutions (62% and 38%), with the university with the more selective entrance criteria having the higher percentage. It is worth noting that between 43% and 63% of those with experience gained it through formal studies, an opportunity not currently available to most Irish undergraduates.

Data relating to the prior experience of over 900 students at the Eidgenössische Technische Hochschule (ETH) Zurich was collected over seven years from 2003 and gathered from 77 students from University of York in 2008 [13]. During this time Computer Science was an optional subject not universally available in either Switzerland or the UK at primary or 2nd level, yet in both institutions, prior experience was high, running at a stable level of 78%-84% across the 7 years. Interestingly, only 16%-25% gained their experience at school, with most reporting self-study as the source.

4 Conclusion

From the results of the survey discussed in this article, it can be seen that roughly a third of those surveyed have had some exposure to programming. To date, a lot of that experience is, necessarily, from self-directed and online study but a surprising amount stems from schools which emerged as an important driver and facilitator for encouraging students into their first steps in programming. Non-school clubs such as CoderDojo have grown in numbers and popularity since their foundation in 2011, however their effect in Ireland cannot be seen as yet in the 3rd-level population. Together with the mooted introduction of programming at primary level and the introduction of Computer Science as a Leaving Certificate subject from September 2018, it is clear that the nature and extent of the prior programming experience of incoming undergraduates will be subject to enormous change over the coming decade.

When examining the profile of freshman students in any discipline, there is always diversity in terms of age, background and general experience. This is a factor that 3rd-level educators have always had to take into consideration when designing courses and choosing appropriate pedagogical approaches. With computer science primary degrees having the highest rate of non-progression in Ireland (varying between universities (15%) and institutes of technology (26%) [15]) it is clearly important that the nature and impact of that previous experience be used as an evidence-base for decisions about future curriculum design and teaching practice, so that introductory courses be made more relevant and appealing to students consequently providing some contribution to student retention and competency levels.

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