Exploring societal factors affecting the experience and engagement of first year female computer science undergraduates

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ABSTRACT

Despite computer science (CS) having many women associated with it historically, such as Ada Lovelace and Grace Hopper, the proportion of female students completing computing degrees is steadily declining, particularly in the USA, UK, and several other Western countries. Many initiatives have been attempted to address this gender imbalance, but the majority have proved to be ineffectual and difficult to sustain in the long term. One important step in the notorious shrinking participation pipeline for CS is the first year of a university degree. The transition from school to university can be a difficult time for many students and, for females in CS, issues of readjusting expectations and of developing their identity within a predominantly male cohort may present an additional challenge.

In this paper, we analyse data from the North American National Survey of Student Engagement (NSSE) and discuss gender-distinct perceptions of the discipline and factors relating to retention of students, particularly female students, within the context of a small UK survey of first-year students' expectations at the start of their studies. We suggest several areas emerging from the investigation which have implications for CS curricula and teaching practice.

Categories and Subject Descriptors

K.3.2 [**Computing Milieux**]: Computers and Education-Computer and Information Science Education

General Terms

Human Factors

Keywords

Computer Science Education, Gender Diversity, Student Expectation, Student Engagement

1. INTRODUCTION

In 2012 the European Union funded a project to encourage womens' participation in Science, Technology and Engineering (STEM). The resulting website, "Science: It's a girl thing!"[1] is available in 24 languages and contains useful resources such as short video clips by women working in STEM. Yet this project came to international attention for a promotional video which portrayed women 'scientists' performing a stiletto-ed catwalk in front of an ogling male. Referred to in the press as 'a viral fiasco'[2] the teaser video was widely condemned as offensive and was quickly removed from the project website. After decades of research and initiatives attempting to attract women to STEM careers, it is interesting to note that large amounts of money are still being spent on getting it completely wrong.

Anecdotally, we have also evidenced rejection by women undergraduates of attempted targeted support, on the grounds that they do not want special treatment. Yet statistics continue to indicate a massive gender imbalance in the subject. These examples show the uncertainty that still exists over 'doing the right thing' in relation to encouraging women to participate in STEM subjects.

For over three decades, initiatives such as the EU "girl thing" project have been launched to encourage more women to enter STEM subjects including computer science (CS). Notable recent research projects eliciting more in-depth understanding of STEM participation and of gender issues in CS include the European Commission-funded "project IRIS" (Interest and Recruitment in Science) [21] and the UKRC's report on STEM role models in the media [11].

Despite the many interventions and research programmes, the indications are that, in Europe, North America and Australasia, we are still failing to make a significant impact on the overall number of women studying and opting for a career in CS. As discussed further below, in many countries, the proportion of women studying for CS degrees is falling.

One important step in the notorious shrinking pipeline of participation is the first year of a university degree. CS in particular has a reputation for high drop out rates [1]. Research by Seymour and Hewitt [23] indicates that there is little difference in terms of student behaviour and motivation between those who stay and those who go. That is, structural and cultural aspects of the educational experience

[1] `http://science-girl-thing.eu`
[2] `http://www.theguardian.com/science/blog/2012/jun/29/science-girl-thing-viral-fiasco`

have more influence on the decision than student behaviour. Further, the issues that are problematic for the leavers are also a source of difficulty for those who decide to stay. Some authors (for example, Ulriksen [26]) have found current attrition rates for female STEM students to be higher than those of their male counterparts. However, even in studies that have found no gender difference in drop out rates, the point is often made that the overall effect given the relatively small number of female starters exacerbates the existing problem.

Given the likely largely systemic nature of reasons for drop out, and the need to support all students better towards successful completion of their studies, there has been a growing recognition that a greater understanding of the student perspective is needed and a variety of mechanisms now exists to gather information on aspects such as student engagement and experience [24]. A further dimension closely linked to these is expectation and this is particularly relevant to first year students who must adjust to a new way of studying and to both subject and university cultures which may be very different to what they are used to at school [9]. However, there is currently very little work examining CS student expectation from a perspective of diversity or which relates this to the broader context of engagement and achievement.

This paper brings together a number of different perspectives in order to better understand the CS first year undergraduate scenario and to investigate the following research questions relating to gender:

- what previous socio-cultural issues are likely to have shaped incoming CS students' identity in Western institutions?
- what does international data tell us about first year CS student engagement?
- do CS freshers' expectations reveal gender differences?

We discuss findings and potential avenues for further research and for course development.

2. METHODOLOGY

Aspects of the current "climate" for women in CS are briefly explored through the literature. In particular, we consider the possible influence of the current state of CS education and of stereotyped attitudes that still exist.

To investigate participation and engagement we draw on public data from the UK and North America where the largest international engagement survey (NSSE) has been administered for over a decade. We compare benchmark results for CS first years against similar figures for students overall and comparable groups in STEM. We provide a comparative analysis of achievement against benchmarks for male and female students.

First year student expectation is investigated via a survey administered to the 2014 intake in the Computer Science Department at the University of Warwick. This local study is part of a wider international effort with participants from Finland, Sweden, Australia and the UK to understand and improve the CS first year experience for all and promote diversity [10].

3. BACKGROUND

Most Western countries now legislate for equality of opportunity. Yet these countries which aspire to be the most gender equal societies in the world appear to be amongst the most entrenched in terms of under-representations of women in STEM education and careers [25]. Despite the large amount of research, initiatives and interventions aimed at increasing female participation in CS, in the USA alone the proportion of women majoring in CS has dropped from around 37% in 1984 to under 18% in 2013[3]. In terms of numbers, this is a fall from around 15,000 to just over 9,000. Obviously, attempts to change or overcome the social and cultural obstacles are not in general succeeding. That the barriers are cultural is suggested by the fact that in some countries this gender imbalance does not occur [18].

The scarcity of women at all stages in CS, possible reasons for this and ways in which the balance can be improved have been topics of concern and research for over three decades. While there are some notable exceptions [17, 3, 12], participation statistics have not in general shown the hoped-for improvement. More recent work has started to move away from a simplistic (and potentially stereotype-reinforcing) consideration of gender differences to focus on more general identity-related factors [14, 6] and the broader concern of CS cultural identity and how diversity can be better supported [7]. Identity-based research has been widely used to provide a deeper understanding of education, in particular, for STEM subjects [13, 15]. Such an understanding can help interpret findings and inform the development of more effective pedagogy [4].

Identity is generally viewed as being constantly under construction through the lived experience of the subject in a social setting. This can provide a fruitful way of investigating the continued and sometimes conflicting gendered CS experiences and influences before, during and after university [16]. *Group roles* are social constructions and identification with a group may lead to an individual incorporating the role as part of their identity. Different identities (for example as a CS student or as a person of a particular gender and race) can introduce conflicting role characteristics. As noted by Madson et al: "The task of negotiating one's identity is a project for all students entering a higher education programme" [15, p328].

4. BEFORE UNIVERSITY: SOCIETY AND SCHOOL

Although in this paper we wish to focus on a specific stage of the CS experience (in this case, that of first year undergraduates), any individual stage is situated within a wider context which affects choices, expectations, identity and the students who do or do not reach that stage or progress from it. In this section we give a very brief perspective on some of the current relevant factors which contribute towards this climate for CS and are likely to have particular resonance for gender identity.

Many factors, from lack of role models to the 'computer nerd' image, have been suggested as contributing to girls' reluctance to study computing at school. To whatever extent such factors might contribute, studies report with depressing consistency a belief amongst classes of all ages that boys are better suited and more capable of studying CS and that

[3]`http://nces.ed.gov/programs/digest/2014menu_tables.asp`

this belief is shared by many teachers [28]. The message of equal opportunity is that everyone should be offered the possibility of pursuing CS, but this may be undermined by the counter-message from many areas of society that girls are still aliens in a world where boys have an advantage [2].

The issue is not confined to CS but applies to science and engineering in general. Toys aimed at boys often promote action while toys aimed at girls often emphasize presentation or human aspects over functionality—notwithstanding the very loud and vehement responses to egregious examples of such distinction. The genderization of toys starts very early [22] and it is unclear (and endlessly controversial) if toy preference is innate or acquired. Several attempts have been made to develop toys that cater to gender preferences while still encouraging aspirations (such as the recently launched *iBesties*[4], which are meant to encourage girls into technical roles). Another school of thought is that toys that are non-gendered (such as the classic Lego bricks in primary colours) are the best to encourage a sense of construction and design in all children regardless of gender). It is particularly important to engage girls through play at an early age since the idea of 'tinkering' and the development of a curiosity to explore and discover is often associated with high levels of success in CS.

Moving from the subliminal to the more explicit advice and information offered, we can still hear about strong anti-STEM messages, particularly within careers advice provided via schools. There is significant interest in finding out whether single-sex schools encourage more female students to apply to STEM subjects in universities and also whether performance of girls is mathematics is better when they come from single-sex schools [5]. Parents also play a crucial role, and a recent survey by the IET revealed that "a staggering 93 per cent of parents would not support their daughter in pursuing a career in engineering" [5].

To end, we should say that even within countries with generally low female representation a few institutions are regularly seeing intakes with up to 40% women [6]. These differing perspectives provide encouragement that the phenomenon of under-representation of women in CS is a cultural issue which can be changed, but a cautionary note that well-meaning interventions may fail to have an effect or, worse, that they may do more harm than good.

5. THE UK CONTEXT

One difficulty in obtaining good data in CS is that the proportion of women on CS degrees is generally very low. Similar to the figures from the USA, in the UK the proportion of female students studying the subject is low and the imbalance can be observed in participation at the school level. UK government figures[6] captured in Table 1 show that in 2004, 12.2% of computing A-level (the main university entrance qualification taken by 17 and 18 year-olds in the UK) candidates were girls but that a decade later this had fallen to just 7.5%. The year 2004 was the first in which CS was separated out from ICT for reporting purposes. Since then, numbers overall have fallen, but most sharply for girls with a drop from 1,032 to 314. From a low of 245 in 2013 there has been a slight recovery in 2014, but the proportion for the past few years has stayed around 7%. There appears to be little difference in achievement between the two groups.

Table 1: Students taking A level CS

Year	Total	M	M %	F	F %
2014	4171	3857	92.5	314	7.5
2013	3758	3513	93.5	245	6.5
2012	3809	3512	92.2	297	7.8
2004	8488	7456	77.8	1032	12.2

Table 2: Students accepted for CS degrees in UK

Year	M	M %	F	F %
2014	20,460	86.7	3,125	13.3
2013	18,785	86.5	2,925	13.5
2012	16,640	86.0	2,715	14.0
2004	5,490	75.1	1,815	24.9

Table 2 shows acceptances to study CS subjects at degree level in the UK which, similar to school figures, shows a decreasing proportion of women[7]. In 2014, nearly a quarter of students on CS degrees were female but a decade later that had dropped to just over 13%.

In the survey from the University of Warwick reported below, 6 out of 70 respondents were female which is not out of line with the national statistics. With such small numbers it is not possible to provide any meaningful statistical analysis, however the results obtained from this small group are offered as indicative of the situation and as suggesting areas for future work. We present some of the basic qualitative results which raise issues relating to the cohort as a whole and in terms of differences between responses from males and females.

6. ENGAGEMENT

To explore the position on engagement amongst CS first year students we use data from the North American National Survey of Student Engagement (NSSE). This survey has been widely administered annually in North America for over a decade, currently reaching participation from 587 institutions and over 323,000 students. The most recent results available aggregate figures from 2013 and 2014. Table 3 collates results for first year responses from CS students, showing comparative figures for males and females. In addition, for purposes of comparison similar figures are provided for first year students overall. In the NSSE survey, each indicator is evidenced by a number of different questions and scores for indicators are all calculated out of a total of 60. A detailed description of questions contributing to each indicator can be accessed from the NSSE website[8].

It is difficult to attach meaning to the basic numbers (for example to compare a 17.0 in Student-Faculty Interaction to a 39.4 in Teaching Practices) but they can be used as benchmarks to review progress of a particular subject both at an institutional level and overall. Given the difficulty of interpreting the raw numbers, one comparison we might (tentatively) make is to the overall cohort. For example, a 17 for Student-Faculty Interaction would be of particular

[4] http://ibesties.com/

[5] http://eandt.theiet.org/news/2015/mar/girls-women-engineering.cfm

[6] http://www.jcq.org.uk/

[7] www.ucas.com

[8] http://nsse.indiana.edu/

Table 3: Comparison of NSSE 2014 Engagement Indicators for CS 1st years/All 1st years (scores out of 60)

Indicator	CS (M)	CS (F)	CS (both)	All (M)	All (F)	All (both)
Higher-Order Learning	37.3	38.8	37.6	38.0	39.1	38.7
Reflective & Integrative Learning	32.3	32.9	32.3	34.9	35.7	35.4
Learning Strategies	35.3	38.3	35.9	37.2	39.9	39.0
Quantitative Reasoning	28.3	25.7	27.8	29.4	24.4	26.1
Collaborative Learning	31.3	31.3	31.3	32.7	32.4	32.5
Discussions with Diverse Others	39.3	40.5	39.6	40.5	40.5	40.5
Student-Faculty Interaction	17.1	17.0	17.0	19.5	18.6	18.9
Effective Teaching Practices	39.4	38.7	39.3	39.3	39.4	39.4
Quality of Interactions	42.7	41.3	42.4	42.0	41.0	41.4
Supportive Environment	35.1	36.8	35.4	35.5	37.2	36.6

concern for CS if the score for students of other subjects was much higher on this indicator. A case like this indicates an area in which there appears to be considerable room to improve for all subjects, but it is not an issue specific to CS.

6.1 Comparison of CS to all students

Firstly, comparing CS results to the overall figures as shown in Table 3, CS is a little lower on all categories except for two in which it is slightly ahead: Quantitative Reasoning and Quality of Interactions. Areas where CS appears to have issues in general are Reflective and Integrated Learning (-5.2%) and Learning Strategies (-5.2%). It is also surprising (but follows the pattern for seniors) that CS is only marginally ahead on Quantitative Reasoning. It might be expected that a wider difference would emerge here. Considering the scores for males and females, the lower rating for Reflective and Integrated Learning appears common to both. It seems likely in this case that for some reason CS programmes are not scoring as well as they might on providing activities which score highly in this category. However, in Learning Strategies there is a 5% difference between CS males and females, with women displaying a greater engagement with strategies likely to promote learning. This follows a similar pattern to the male/female split for this category overall. A second notable area of difference, and again one which follows the pattern for all students, is in Quantitative Reasoning where males rated their engagement 4.3% greater than females.

The patterns of difference both within the CS cohort and in comparison to overall performance is similar to that observed in the data for senior students except that the gaps become larger and CS appears to fall further behind against the engagement measures as students progress through their degree [24]. This is in contrast to other subjects where gradual improvement on most measures is noted. Why this happens in CS courses is an area for further exploration.

6.2 Comparison of CS Engineering and Physical Sciences

Table 4 shows comparative figures for CS first years against two groups which are likely to have similar profiles to CS: firstly, Engineering and secondly, Physical Sciences other than CS. Similar to the position for CS, these two comparison groups both have lower than average scores for Reflective and Integrated Learning and Learning Strategies and have similar gender profiles within these two indicators. However, both of the other two groups score more highly than CS for Collaborative Learning (+4.7% for Physical Sciences and +10.0% for Engineering) and Quantitative Reasoning (+5.7% for Physical Sciences and +6.8% for Engineering). It seems reasonable that particular subjects have distinctive profiles in which some indicators achieve higher scores in general and others lower. But CS does not seem to be doing well against engagement measures in which other STEM subjects are leading. As with other STEM subjects, it would seem that CS should afford good opportunities for aspects such as collaborative learning and that quantitative skills would be developed. This is a finding that warrants further investigation.

6.3 Level of challenge

An additional question in NSSE asks students about the extent to which they have found their course challenging, with responses on a scale of 1 (not at all) to 7 (very much). A response of 6 or 7 is regarded as an indication of a highly challenging course. For CS, 49% of students overall regard their course as highly challenging which compares to 54% of students across all degrees, 51% in Physical Sciences and 57% in Engineering. Across all courses, more women than men state that their degree is highly challenging. In CS, 54% of females and 48% of males choose this rating. This compares to 57% of women overall and 63% in Engineering. It is surprising that, despite its reputation for high dropout rates and the reported difficulties in learning programming, CS students generally report a relatively low degree of challenge. The most usual interpretation of high attrition figures is that CS, and programming in particular, is too hard for many students, yet the NSSE figures might lead us to question this.

The differences noted above point to issues which may be useful to explore and may indicate areas in which CS courses could better support students. However, there are also issues regarding the interpretation of questions and allowed responses, and the self-reporting of these figures. These may have implications for how students from a particular subject answer and may also (as a generalization) be answered differently by males and females. These issues are discussed further in Section 6.

7. LOCAL SURVEY RESULTS

As part of a wider study on first year experience in CS, a survey of incoming CS students was conducted at the University of Warwick for the intake of 2014. The survey was administered in the second week of the first term and re-

Table 4: Comparison of NSSE 2014 1st years from CS/Physical Sciences/Engineering (scores out of 60)

Indicator	CS (M)	CS (F)	CS (both)	PS (M)	PS (F)	PS (both)	Eng (M)	Eng (F)	Eng (both)
Higher-Order Learning	37.3	38.8	37.6	39.0	39.7	39.4	38.3	39.3	38.6
Reflective & Integrative Learning	32.3	32.9	32.3	33.8	33.6	33.7	32.4	32.3	32.4
Learning Strategies	35.3	38.3	35.9	36.7	39.6	38.2	35.9	38.5	36.6
Quantitative Reasoning	28.3	25.7	27.8	32.4	30.0	31.2	32.3	30.6	31.8
Collaborative Learning	31.3	31.3	31.3	33.5	34.6	34.1	36.8	38.8	37.3
Discussions with Diverse Others	39.3	40.5	39.6	40.6	41.0	40.8	40.9	42.7	41.4
Student-Faculty Interaction	17.1	17.0	17.0	19.9	19.5	19.7	17.7	18.2	17.8
Effective Teaching Practices	39.4	38.7	39.3	40.3	40.1	40.2	38.1	37.4	37.9
Quality of Interactions	42.7	41.3	42.4	43.0	41.8	42.4	41.8	41.1	41.6
Supportive Environment	35.1	36.8	35.4	35.9	37.7	36.8	35.5	37.8	36.1

sponses were received from 70 students. Questions covered topics on student background (such as previous programming experience and level of achievement in mathematics), their expectations for the degree (including topics of study and expected methods of study) and their feelings about their own preparedness and likelihood of success. Participants could remain anonymous but optional inclusion of student numbers was suggested in order to support tracking through future surveys.

7.1 Background

7.1.1 Programming

Of the 64 male respondents to our survey, 12 (19%) had no previous programming experience compared to 3 (50%) of the females. Of those with programming experience, the women had all programmed at school (although one had in addition written programs for fun and as part of work experience). A similar proportion of males (49%) to females (50%) had programmed at school but 53% of males program for fun compared to the single female leisure coder (17%). The most usual programming language for all students to have used previously is Java (44%) with Python (36%) and Visual Basic (30%) also quite popular. All of the females with previous programming experience had written programs consisting of over 50 lines of code, whereas for 11% of males the experience was of small programs less than 50 lines in length.

7.1.2 Mathematics

As mathematics requirements are part of the course prerequisites (unlike computing) there is little difference between genders in terms of mathematical attainment. All students have mathematics A level and most have Further Mathematics A level as well. Although females are as well qualified as males, no female felt “better than average” in the class whereas 22% of males did.

7.2 Expectation

7.2.1 Hours of work

In line with many previous studies, most incoming students appear to underestimate the number of hours of work that they are likely to be doing. Overall, only 11 (16%) students thought they would spent 35-40 hours per week and just 2 (3%) envisaged studying for more than 40 hours. On average, males thought they would spend 25 hours per week and females estimated 22 hours.

7.2.2 Study activities

Table 5 shows students’ expectations of the types of study activities they will engage in. Overall, the majority of students expect to do all of the activities listed at least sometimes, apart from participation in discussion forums. In the case of preparing for class and attending teaching sessions, males display a wider variety of expectations. It is interesting to note that over 20% of males think that they will rarely or never study with peers whereas all of the girls recognize that this is likely to form a substantial component of their study.

7.3 Self-perception

Table 6 shows the students’ confidence levels regarding a variety of skills. Again, some aspects such as writing reports receive a more mixed response from males. On the whole, females are more likely to express reasonable confidence levels about their skill-based abilities. In particular, no woman was either ‘not at all confident’ or ‘dreaded’ report writing or giving presentations whereas over 20% of men chose those options for each of these categories. Similarly, no woman expressed the opposite extreme of being ‘very confident’ about giving presentations or working with a group, whereas 8% and 23% of males chose this option for the two categories respectively.

A majority of all students expressed concern over a range of factors which might adversely affect their ability to study. Areas where males were notably more anxious were: poor planning (+10%) and procrastination (+23%). Areas more of concern to females were: estimating workload (+11%) and prioritising(+8%). The ability to study effectively and the deployment of information retrieval skills were of equal concern.

These findings suggest that there are things our courses can do to help prepare students for their studies and to better support them in their transition from school to university study. The high levels of concern over skills preparedness indicate that these are important factors to address. This needs to be done in an integrated way to make tasks seem relevant and meaningful. Although some factors are more of an issues for males and other for females, it is likely that support in these area will be of benefit generally.

The NSSE results reported in the previous section give data relating to established, internationally recognised engagement benchmarks (within which, specific items such as

Table 5: How often (%) first year students anticipate engaging in learning activities

	Very often		Often		Sometimes		Rarely		Never	
	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%
Preparing for class	14	0	52	83	28	17	5	0	0	0
Attending lectures	91	100	8	0	2	0	0	0	0	0
Attending labs and tutorials	89	100	11	0	0	0	0	0	0	0
Working on assignments	50	67	45	17	3	17	0	0	0	0
Working using online resources	11	0	58	67	28	33	8	17	0	0
Participating in discussion forums	0	0	11	17	34	33	39	33	14	17
Studying with peers	3	17	28	17	50	67	13	0	8	0
Further reading and investigation	9	17	38	67	45	0	9	0	0	0

Table 6: First year students' confidence at transferable skills (%)

	Very		Fairly		Not very		Not at all		I dread this	
	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%
Writing reports	6	17	55	17	20	67	11	0	8	0
Giving presentations	8	0	47	33	23	67	14	0	6	0
Working with a group	23	0	58	67	15	33	2	0	0	0
Learning through reading	30	67	47	33	19	0	2	0	0	0
Managing my time	19	17	59	83	19	0	2	0	2	0

development of transferable skills and level of activity relating to higher-order learning practices form key indicators). However, they contain no information on why students report as they do, how students feel about their studies or how their identity as a CS student develops. The data reported in this section begins to ask questions which can establish a baseline of understanding about the feelings and thoughts of our incoming students. As noted by Hughes [8] (and as we would hope) our teaching is influential on students' identity development. If students have misconceptions about what CS study involves or they are very apprehensive about certain aspects of the work or university life, then knowing this enables staff to better cater for students' needs as they make the transition from school to university. Our data shows that many new students do not have a realistic idea of what to expect and that, despite being very enthusiastic about their course, many are highly apprehensive about certain aspects of it. Much influential work on retention points to the important role of socialization and integration as a complex process by which students negotiate their relationship with the culture and environment [27]. Developing an understanding of different students' perspectives and expectations is vital in order to support and encourage the ongoing engagement of a diverse student population.

8. DISCUSSION

The different perspectives represented in this paper serve to situate the first year CS experience within a broader narrative of likely previous influences and future possibilities. It is true that other STEM subjects have a similar gender imbalance to CS. However, one of the most worrying aspects of the situation is that, whereas for subjects such as Engineering, there has been a steady if gradual rise in female participation to the present numbers, the proportion of women studying CS (and in some cases the actual numbers doing so) has fallen. It seems that in general, the enthusiastic message that this is a great subject for girls to choose is not being accepted. In order to ensure that initiatives are not misdirected (as with the 'Girl Thing' video) we need further understanding of why this might be and why the graph is moving in the opposite direction to Engineering.

Previous exposure.

In terms of the experience of incoming CS students, our data suggests that amongst the few women who do choose CS, there is a divide between those who have no programming experience but want to give it a try, and those who are already highly committed to the subject and have programming experience. Although with so few students the results can be regarded only as possible areas for further exploration, it appears there are fewer "middle ground" women. Another feature if the data is that most male students have already been programming for their own enjoyment. It is interesting that 5 out of our 6 women respondents were committing themselves to at least 3 years of intensive computer science study without having tried any programming or, for those who did so at school, not seeing it as something they wanted to do outside their taught activity.

The data also suggests that those with considerable experience, both in maths and in CS, do not rate themselves as being above average, whereas men with similar or lower levels of qualification often do. This is in line with much previous research. However, in terms of self-efficacy there is little difference, with responses from both males and females indicating an overwhelming belief that they will succeed in their CS studies. A higher proportion of women start with no programming experience.

School and progression to university.

For the UK and countries with similar educational systems, the game for many is already lost by the time of university choice. Of course, we need to retain the women who enter CS degrees, but there are very few to start with. Schools are therefore hugely important. In the UK, the state of flux in CS teaching in schools leaves us in a difficult position. Hopefully, this will change as the new curriculum beds in and pupils progress through the school system but currently highest level of school qualification seem to be very limited. Our findings that fewer women entrants have computing qualifications or programming experience is therefore hardly surprising. The lack of prepared teachers means that teaching is patchy and inspirational, innovational teaching is a crucial factor here. Here again, although concepts of gender identity may be an underlying issue (as suggested by the statistics) the solutions are likely to be improvements which benefit all pupils. Further work, such as that by Peters and Rick [20] is needed to establish how, in practice, development of CS identity can be fostered in a school classroom setting.

A recent study commissioned by Google found that the factors most likely to have an influence on girls' decisions to study CS were encouragement and exposure to ideas [29]. Girls are significantly more likely than boys to be dissuaded from studying CS by negative parental pressure. This work underlines the importance of positive encouragement from parents and others and the role that schools have to play in presenting CS as an exciting and relevant subject.

Although other STEM subjects share some of the same challenges in recruiting and retaining women, the current climate for CS presents particular differences which may account for further imbalance:

- at school level (and in general) there is a worrying lack of understanding about the subject, with many people still wondering if CS is just ICT, if it equates to programming, or to software engineering, or a more foundational discipline, or based on applications;
- there is a lack of opportunity in school to learn about CS; many countries are only now introducing computing into the core school curriculum, with an introduction to programming and also exposure to interactive systems such as Arduinos and Raspberry Pis;
- there may be a particular image problem with CS as being the domain of socially awkward men, with the history of progress characterized by many advances made by individual males working alone or small teams of friends in little garages.

Where these barriers are found to exist, it is in universities' own interest to help counter them and ensure the future health of the subject.

It also still seems likely that, in some countries, girls' opportunities to study CS at school are more limited. For example, anecdotally, in UK schools girls may currently have less access to A level computing courses than boys. This was certainly the case at our recent summer school in which 40% of the participants were girls and none of them attended a school which offered A-level computing. Girls are therefore not having the same exposure to CS or given the same routes into a degree.

Issues for CS and CS teaching.

The important role of schools does not remove the responsibility from universities. We need to retain students and to ensure that, as and when students come through from exciting school curricula, the level of expectation and excitement about the subject is maintained. Universities must continue to enthuse and motivate students through the way the subject is taught and actively encourage diversity through the environment provided. Some of the NSSE findings suggest that CS courses at university may not in general be doing as much as other subjects to promote innovative teaching and to offer high impact learning activities. One message that has consistently emerged from successful programmes to attract women to CS, such as that of Margolis and Fisher [17] is that, very often, the best actions are those which promote better teaching, learning and support for *all* students. Student engagement surveys indicate several areas which CS programmes could look to improve such as in encouraging innovative teaching practices and using more methods known to foster deeper learning.

The approach advocated by Klawe at Harvey Mudd College in the USA addresses these issues by suggesting an approach of: "increase interest, increase confidence, encourage" [12]. One practical step in this direction is to change the strategy for the first-year from 'learning to program in Java' to more general 'team-based creative problem solving in science using computational approaches'. Similarly, a number of universities now choose a more accessible first language such as Python or even Scratch. These measures allow students to access programming more easily and can help them to concentrate on computing concepts and applied problem-solving without having to invest a lot of time initially on mastering syntax. These strategies are both examples of changes which can potentially be of benefit to both males and females. However, they are clearly most helpful for students who have not had the opportunity to access effective computing teaching at school or who fail to find encouragement at home. The data in Table 1 above clearly shows that in the UK far fewer girls than boys are taking CS qualifications in school. While students' choice (however strongly influenced by societal factors) is likely to be mainly responsible for this, there is anecdotal evidence that, currently in the UK, girls' schools and non-selective (mixed) state schools are still less likely to offer CS qualifications than boys' schools. This is an area which needs further investigation. However, if girls have fewer CS opportunities and less encouragement at the school level then this might provide one reason to suggest that interventions at university level to support all students may provide even greater benefit for female students.

Stereotypical, societal identity roles which affect CS participation undoubtedly exist and these need to be challenged. In the past, many initiatives to improve the recruitment and retention of women in CS have been based on identifying and seeking to cater to gender differences. The track record of success of such initiatives has not always matched the enthusiasm of their implementation (and indeed there seems often to be a lack of effective evaluation of such initiatives). A number of authors note the danger inherent in using perceived gender differences as a basis for discussion and intervention. Løken states that "by repeating the meta-narrative without emphasizing the nuances, we can contribute to self-fulfilling prophesies" [14, p290]. There is likely to be as big a difference between female CS students as there is between students of different gender and it is helpful to consider differences as and where they occur rather than presenting or working to support narrow characterizations [25].

With the proportion of women studying CS at university still declining rather than increasing, we are inclined to agree with previous commentators that a narrow approach based on gender differences may limit a more meaningful effort to encourage true diversity in which a range of characteristics, skills, abilities and so on may cut across simplistic, stereotyped boundaries [7]. Focusing on the culture of CS courses and the climate in which they operate may provide a greater understanding and more fruitful approaches to intervention. However, it is still necessary to investigate the perceptions, expectations and levels of achievement of under-represented groups to understand the cultural factors which may be adversely affecting their entry or progression, at whatever stage these may occur. Cultural issues of gender role expectation or direct pressure (for example, from parents who attempt to dissuade daughters from studying CS) still need to be identified and challenged. Perhaps our mantra should be "challenge stereotype: support all"!

Engagement and expectation.

Results from NSSE (and also from other surveys such as the Australasian University Engagement Survey) report low scores for CS in a number of aspects, indicating areas of concern for CS teaching. The Learning Strategies category is significantly lower than for the overall group (students of all subjects). However, in this respect CS women report much higher application of learning strategies, indicating a greater maturity than their male counterparts in self directed learning. However, male CS first years report higher scores on quantitative reasoning. As the data is elicited using self-assessment questions, it may be the case that women have tendency to report differently to men. Studies have often noted that men answer with greater confidence than women even when they are no more likely to be correct. This is confirmed by our results on students' self-assessment of position with respect to the rest of the class. We are not aware of any work relating to this in the context of interpreting engagement survey results, and further work is needed to determine why the observed differences are occurring. This could identify areas where additional support or different methods of teaching would be appropriate.

It is interesting that new first year students continually underestimate the amount of time needed for studying. It may be that many are used to being the 'top of the bunch' at school and have been able to achieve high grades without needing to study for long hours. Low estimation of study hours is observed for both males and females but, in our small sample, women expect to work for even fewer hours (22 per week) than men (25). There is also low score on perceived challenge in our survey. It may be that the difficulty of departments in coping with a huge range of students means that for some (both male and female) there is a very steep learning curve whereas for others the first year is relatively easier than it might be.

This raises an interesting possibility: perhaps for some, drop out is not necessarily because the studies are too hard, but in fact easy (or syntax-driven) and lacking in interest. An emphasis on programming instead of the *application* of programs to realistic scenarios may limit interest and render topics less engaging. The subject may appear dry and irrelevant—particularly to female students for whom, as some studies suggest, social relevance and connection to real-world issues is particularly important [17].

Identity.

We have noted some of the disturbing societal messages which still persist in presenting a stereotyped gender identity in which STEM subjects such as CS are subtly - or nor so subtly - tagged as being more for boys than for girls. Work by Hughes suggests that different curricula and different methods of teaching can make different potential identities available to students [8]. Ulriksen et al sum this up by saying: "The way science is presented to students set(s) the scene for their participation in science and produce(s) a wide range of subjectivities the students can relate themselves to in their identity-work" [27, p212]. Rethinking the CS curriculum to consider what effect it has in this respect may be beneficial, not just to women, but to all students forming their identity as CS students, and help each individual (rather than groups supposedly characterised by certain features) access a CS identity relevant to them and thus make the curriculum genuinely more inclusive.

Many initiatives promoting CS as a good subject choice for women appear to rely on defining a particular image of girls (girly, geeky, family-loving). But for all of those to whom such an image appeals, there will be others who do not relate to these portrayals. For example, for students who are less sure about their ability, the portrayal of the subject as brainy may not be helpful. Why should girls have to see themselves as particularly brainy to enter a CS career? For any one gender image publicity tries to portray, it will appeal to some and be off-putting to others. The "It's a girl thing!" video is just one (if rather extreme) example of this. We should therefore beware of trying to replace one stereotype with another and seek to develop curricula and pedagogy which take an inclusive approach. Again, this is another example of what is best for all is best for women and an area in which further research is needed to identify what such pedagogy should be.

It has been noted elsewhere that CS courses do not provide good support for students in developing their identity as CS professionals, and that "in order to support negotiation of meaning, education needs to address students' current experience of participation" [19]. Further understanding of the students' perspective, both at the start of their course and as they progress in constructing their relationship with the institution and the subject, is needed in order to inform strategies which will support continued, successful participation the course.

Conclusion.

The issues raised in this paper are complex ones and, as evidenced by the long history of attempts to attract more women to study CS, there is unlikely to be a simple fix. We also note that many similar strategies have been used in other STEM subjects such as Engineering yet in these cases a gradual increase in the proportion of women undergraduates has been observed. Again, it seems there are other perhaps cultural reasons for the lack of progress in CS which we still need to identify. The wider discussion in this paper is largely generic and much of it applies in many countries. However, several UK-specific factors are also mentioned. It is likely that issues affecting attitudes and participation in any specific region will be a combination of both general and local influences. When planning any intervention at a local level it is therefore useful to consider both.

The data from NSSE and from our own survey point out some interesting factors relating to students' previous experience, expectation and engagement which may be contributory factors to first year student drop-out rates in CS and which may affect women in particular. When taken in the context of low enrolment numbers to begin with, we are left with a severe under-representation of women in CS. There are indications that gender stereotypes and cultural expectations are still highly influential in girls' decisions not to take CS. However, there are also worrying suggestions that practical barriers (such as the opportunity to take CS qualifications at school) may still exist for many girls. In terms of the curriculum, inclusive measures which appear beneficial include good teaching; exciting, problem-based courses; encouragement and support; accessible introductory courses. As noted above, there are indications that, while beneficial for all students, such measures may be particularly helpful for women. The secondary benefit of this approach is to enrich the image of CS education in general for all students and keep the interest in the subject healthy into the future. However, it is equally important that interventions to increase engagement counter-act the many societal images which constantly tell female students that a CS degree is not for them.

Although we do not have sufficient data to allow firm conclusions to be drawn, we bring together here a number of points arising from the discussion which appear to be important in the context of increasing females' participation and engagement in CS at undergraduate level.

- Undergraduate CS teaching in general appears not to be as innovative or focused on acknowledged deep-learning practices as other subjects. This may also affect the complex process of identity formation.
- There appear to be reasons why some "good for all" improvements may benefit women even more than men.
- Encouragement and positive presentation of CS is influential in girls' choice of subject.
- Access to the subject at school level is very important and may be unequal for girls. Universities need to consider what they can do to reveal problems and help implement solutions.
- More women than men may be choosing to study a CS degree without having any programming experience and without previously having shown an inclination to try writing programs in their own time. Again, this has implications for the support needed to help all students with no programming experience to form their identity as CS students.

Each of these points to practical areas in which action could be taken. They are also areas that warrant further investigation contributing to a climate in which future teaching initiatives and interventions can be research-based and their effects evaluated.

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