In search of self-efficacy: development of a new instrument for first year Computer Science students

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Abstract (150 words)

This study explores the changes in Computer Science (CS) students' self-efficacy between entering study and the end of first year of university. It aims to give course leaders insights into the everyday challenges that affect students' academic achievement and persistence into second year. The paper begins by proposing that the way CS is taught, the gender imbalance on CS courses, and the experience of the key transitional year into university might influence CS students' non-continuation. It adopts an academic buoyancy conceptualisation of resilience. Acknowledging the scarcity of instruments covering CS students' transition to university, the development of a new 20-item questionnaire is described, based on CS students' own contributions of the challenges they faced during first year. The instrument is administered twice in one session to the same cohort. Analysis of paired responses indicates a loss of confidence to overcome challenges in most aspects, particularly staying motivated to study.

Keywords: self-efficacy; academic buoyancy; computer science; first year experience; motivation

1. Introduction

The purpose of this paper is to document the development of a new instrument to elicit the self-efficacy of students entering the first year of undergraduate Computer Science (CS) courses.

The instrument was developed with first year students, based on the everyday challenges they reported having experienced during their first year of study. It is hoped that such an instrument can be helpful in developing meaningful interventions for students who identify themselves as potentially low in self-efficacy. Such students may be at risk of non-completion of their first year studies and thereby unable to proceed to second year.

The context of this study is the persistently, troublingly high non-continuation rate of Computer Science undergraduates: of all UK-domiciled young entrants to full-time first degree courses, those studying CS-related subjects are the least likely to be in their course in second year, regardless of the qualifications they entered with. The figures for 2013/14 show a 9.8% drop-out rate before second year (Higher Education Statistics Agency, 2016a) that is at 17.2% even higher for mature students (Higher Education Statistics Agency, 2016b).

2. Factors influencing poor retention figures in CS

This study proposes that non-progression arising from academic failure in first year CS may not be explained entirely by inability to program, and considers whether CS is taught differently from other subjects, whether the CS student body might possess different characteristics from its peers, and whether CS students experience the first year in university differently.

2.1. Challenges associated with settings for CS teaching

Classes in introductory and general CS modules are often very large, with first years commonly in lectures of over a hundred students. In their study of the gender-based confidence gap amongst STEM students, Sobel, Gilmartin & Sankar (2016) recommend reducing class sizes and not putting students who are "new to Computer Science in the same introductory classes as (mostly male) programmers with years of coding experience", some of whom report programming to be a "source of extra-curricular pleasure" (Rowan, 2015). Their findings, that female CS students are less likely to ask questions in class, may also apply to low-confidence males, and they recommend tools enabling anonymity to increase participation.

Kirkpatrick suggests (2016) that when CS students are working on their own and they encounter challenges that interfere with their academic progress, they may be deterred from seeking help from their peers or academic staff. Berland, Davis, & Smith (2015) cite features specific to CS classrooms that can hinder interaction between teachers and students: the content is technical; students often look at screens throughout the session; program code takes a lot of time to read, and it can be intricate; content and contexts change frequently. They argue for classroom design and tools that: allow teachers to see students' faces; do not require the full attention of either teachers or students; and allow for movement and group work.

For Beck & Chizhik (2013), switching to small-group co-operative learning or pair programming means the problem-solving process becomes more supportive and less competitive, with improved communication (Zarb & Hughes, 2015). They suggest this would change the atmosphere of the CS classroom and be more participative not only for women and minorities, but also for some male students. Berland et al. point out, however (2015), that few material resources explicitly support CS teachers' use of collaborative approaches.

The review carried out by Israel (2015) of studies on the effectiveness of integrating MOOCs for teaching CS in traditional university settings for blended or flipped classroom contexts, found that, while students performed as well as in a face-to-face settings, their satisfaction was lower, and centred mainly on the lack of interaction.

A further alienating factor may be that the key success criterion in programming assignments, that the program should compile, is black and white compared to the scope in marking written assignments and, arguably, rather unforgiving towards the novice programmer (Gordon, 2016). This contrasts with the range of marks that can be awarded for written assignments. The binary nature of a program's key success criterion – it either works or it doesn't – places the onus on students to persist until they succeed in making it work, or risk a failing mark.

2.2. Gender as a possible factor in CS students' self-confidence

Despite the best efforts of outreach programmes (Lang, Fisher, Craig, & Forgasz, 2015), figures for 2015/16 show that the gender imbalance in CS is the greatest amongst all subject classifications in UK universities (Higher Education Statistics Agency, 2017). While the proportion of female undergraduates studying Engineering and Technology, the next most imbalanced subject, is 16.1%, females account for just 14.8% of CS undergraduates. Hillman and Robinson report that across all subjects, 8% of men, compared to 6% of women, are not in higher education following their year of entry (2016), but this alone cannot account for CS having the worst non-progression rate of all subjects.

In the UK, females record the higher number of admissions and completions, and, by a small margin, better degree classifications, averaged across all subjects. In comparison with 69% of males, 73% of females achieved "good" degrees (First Class/2:1) across all subjects (Higher Education Statistics Agency, 2016c). By contrast, Wagner reports in her extensive comparison of Computer Science with four subjects (2016), that in only Computer Science were females awarded "significantly fewer first class degrees than males".

The National Student Survey, the UK's most comprehensive survey of students' attitudes towards their course, is administered in their graduating year, long after the risky first year period of interest to us. It is noteworthy that in 2016, of the 21 disciplines included, only Mathematics and Combined Studies finalists gave a more negative response than Computer Science students to the statement: "The course has helped me to present myself with confidence" (Higher Education Funding Council for England, 2016).

Yorke, in a study (2016) reporting the development and initial use of a survey of student belongingness, engagement and self-confidence, found that males were more self-confident than females, but less academically engaged. This is echoed by Schnell, Ringeisen, Raufelder & Rohrman's finding (2015) that, despite greater confidence in their academic abilities, "male students have consistently been found to use self-regulated learning behaviours less effectively than girls". However, Pollack proposes (2006) that undergraduate males may "present a 'mask of bravado or pseudo-resilience' which may project confidence yet hide a troubling sense of isolation".

Sobel, Gilmartin & Sankar's findings (2016) detect a "positivity bias", or "over-confidence in ability relative to performance", by the male CS students. This supports Allan et al.'s findings (2014) that "high competence and trust in their own abilities was evident in male inductees, which may mean that some students over-estimated their capabilities at the outset of their studies".

Students' own estimations of their performance is inconsistent: Kinnunen and Simon (2012), describing students' own perception of programming assignments they have just undertaken, find that some students reflect negative views of their efficacy, even after having a positive programming experience.

3. Academic buoyancy as a feature of successful transition to university

In the context of poor CS progression rates into second year, students' resilience in the face of challenging situations and circumstances during the transitional first year becomes very important. The common conceptualisation of resilience is of the ability to recover from unusual ordeal. From its beginning as an area of research into coping with adversity, eg, Connor and Davidson (2003), resilience as a field of psychopathology has shifted towards conceptualisations of "competence in the context of high adversity" (Masten & Tellegen, 2012). Atkinson, Martin, & Rankin (2009) describe resilience in heightened terms as the "capacity to recover from extremes of trauma, deprivation, threat, or stress".

Cassidy (2015), however, contests the existence and relevance of a global resilience construct. He argues instead for "resilience to be considered—and measured—as a context-specific construct", and refers to academic resilience as an increased likelihood of (academic) success despite environmental adversities.

However, extreme adversity affects a minority of students, rather than the mainstream majority. It does not adequately explain almost 1 in 10 CS students failing to progress, or else other disciplines would suffer a comparably high drop-out rate. Instead, we propose that the challenging situations should be defined in terms of Martin's academic buoyancy model (2013), based on the premise that an agglomeration of routine, low-level impediments is as likely to damage academic achievements as instances of life-changing adversity.

The basis for Martin's 2013 model, Martin & Marsh's model of academic buoyancy (2008), defines it as "withstanding and successfully responding to *routine* [my emphasis] school challenges and setbacks" (Putwain, Daly, Chamberlain, & Sadreddini, 2016), and positively associates it with self-efficacy and academic achievement. Academic buoyancy is arguably applicable to a greater proportion of first year students, alongside recognition of the social, financial and environmental factors involved in successful transition to university. Collie, Martin, Bottrell, Armstrong, Ungar & Liebenberg (2017) characterise academic buoyancy in students as overcoming "typical setbacks and challenges that occur as part of their education".

Giving nuance to this 'routine' and 'typical' description of academic challenges is Martin's work (2013) suggesting that academic buoyancy might be more relevant to reducing minor negative outcomes, while academic resilience might predict major negative outcomes, such as outright disengagement.

While there is a case for re-conceptualising adversity to address the mainstream majority, Collie et al. (2017) point out that academic buoyancy may still be relevant to students with special needs, since the accumulation of small setbacks "may make more major or chronic challenges typically facing these students even more difficult to manage". According to them, buoyancy refers to an appraisal of responses to past adverse experiences, and can result in either academic achievement or premature abandonment of study.

Broome & Darwent (2014) propose three core elements in successful transition to HE: self-efficacy; self-regulated and autonomous learning; social integration. Allan, McKenna and Dominey assert (2014) that inductees to higher education are "increasingly vulnerable to stressors during transition", and their study correlates mental resilience with academic success.

Finally, many researchers and practitioners advocate strategies that universities can employ to promote social integration during the transitional first year, including McPhail (2015), Morgan (2013), and Jones & Thomas (2012).

4. Desirability of a new self-efficacy instrument specific to the CS first year experience

This paper proposes that the difficulties CS students face in their first year, and their reasons for failure to progress, range beyond academic failure to the challenges inherent in adapting to a new institution. It builds on the positive association between academic buoyancy, self-efficacy and academic achievement proposed by Martin & Marsh (2008). The broad range of first year challenges includes a higher level of learning, new social relationships, less structure and support than in school or further education college, and in many cases, living independently or working alongside study for the first time. In this context, self-efficacy denotes the students' confidence in their ability to meet these new challenges.

According to an extensive review carried out by Bartimote-Aufflick, Bridgeman, Walker, Sharma, & Smith (2016), self-efficacy is the single most important (and reliable) predictor of university student achievement in recent decades. Collie et al. make the point that, although similar, there are differences between buoyancy and self-efficacy. They define self-efficacy as a motivational construct (2017), directly citing Bandura's definition of the student's "sense of agency in relation to future experiences" (2001).

Bandura's proposition is that "there is no all-purpose measure of perceived self-efficacy", and encourages the construction of new instruments relevant to the area and subjects under investigation, employing the self-efficacy scale in novel settings. As Bandura explains, "the content domain should correspond to the area of functioning one seeks to manage ” (Bandura, 2006, p. 311).

The number of recent studies of the first year HE experience with particular regard to CS students is small, and they are limited in different ways. Firstly, some studies provide valuable focus on self-efficacy during the transition, but without addressing CS students. For example, in their British study, Nightingale, Roberts, Tariq, Appleby, Barnes, Harris & Qualter (2013) emphasise the importance of emotional self-efficacy in adjusting to university, because of the independent effect it has on academic outcomes, owing to differences between beliefs about the ability to perform a behaviour and actually performing that behaviour. Paciello, Ghezzi, Tramontano, Barbaranelli, & Fida (2016) place an emphasis on the importance of social self-efficacy during the transitional phase. Again, their study is not directed towards CS students.

Others, such as Sinclair, Butler, Morgan, & Kalvala (2015), have criticised the lack of subject specificity in the questions of the large scale NSSE, SES and UES student engagement surveys used in North America, the UK and Australia. In their review, Sinclair et al. cite in particular the unsuitability of written reports as measures of higher order learning in CS students.

Most studies employ a deductive approach and apply pre-existing scales or use a proxy for self-efficacy. Stoliker & Lafreniere (2015) use Sullivan’s (2010) Academic Coping Strategies Scale (ACSS) to assess how students cope with academic stressors. While Sanders, Mair & James’s study (2016) concentrates on the first year of HE, it employs the Academic Behavioural Confidence scale that has not been used reliably by other researchers. Collings et al.’s study (Collings, Swanson, & Watkins, 2016) also focuses on the first year experience using a specially constructed Student Well-being Scale, but neither it nor the ACSS have been formulated with CS students in mind.

Veilleux, Bates, Jones, Allendoerfer & Crawford (2012) concern themselves specifically with CS first years, and examine engagement, retention and persistence in CS using five items from the Motivated Strategies for Learning Questionnaire, with higher values representing a greater sense of self-efficacy.

There is a considerable body of research focusing more narrowly on programming self-efficacy, including a widely-referenced seven-point programming self-efficacy scale (Ramalingam & Wiedenbeck, 1998) which proposed four factors which they labelled independence and persistence, complex programming tasks, self-regulation, and simple programming tasks. It is adaptable to other languages, and later used by Askar & Davenport (2009) as a basis for assessing students’ Java programming self-efficacy. Lin’s perspective of self-efficacy (2016) encompasses learning self-efficacy, computer self-efficacy and programming self-efficacy, adopting previously-validated scales to assess each: Pintrich, Smith, Garcia, & Mckeachie (1993), Compeau & Higgins (1995), and Ramalingam & Wiedenbeck (1998).

Self-regulated learning in programming is only one, albeit important, aspect of the first year CS student’s experience. In order to construct scales to assess self-regulatory efficacy, in which students persist despite the impediments to learning, a list of transition-related items specific to the first year CS experience would be necessary. Bandura states that "constructing scales to assess self-regulatory efficacy requires preliminary work to identify the forms the challenges and impediments take" (2006); as Ramalingam, LaBelle, & Wiedenbeck point out (2004), a person may have high self-efficacy in one domain and low self-efficacy in another. We therefore decided to employ an inductive approach to item generation and ask first year CS students themselves to provide the challenges and impediments that would form the basis of the questionnaire.

5. Construction of a new self-efficacy instrument

The study takes place in a Scottish post-1992 university. The cohort from whom participants in the development were taken is two thirds Scottish, with the rest mostly from EU states, and a minority from the rest of the UK and outside the EU. The study received ethical clearance from the university's Research Integrity Committee.

5.1. Participants during item generation

A convenience sample of 12 students who had just completed their own first year CS studies was sought from the cohort of 148 who began the academic session that September. Contacting students who had failed the year, in order to minimise bias in the contributions, proved fruitless. The population of 118 students who had finished with the requisite credits to proceed into second year were targeted, and as students had finished classes for the summer, recruiting a modest 10% sample was realistic and achievable. A decision was taken that these students would act as experts, contributing suggestions for items, which other members of the population would evaluate (Stewart, Lynn, & Mishel, 2005).

First, the researcher contacted the outreach secretary of the university's software development student society, who had himself just finished first year in the School of Computing. Following a mailshot, 12 students expressed interest in helping with the research and were sent an e-mail (e-mail communication, 2015) providing an explanation of the project, and an explanation of their role as experts. The e-mail asked them to consider their own experience and each provide a list of around ten "everyday challenges and impediments that can affect first year undergraduates' academic activities". All the students had completed their first year of several computing degrees (BSc Business Information Systems, MEng and BEng Software Engineering, BEng Computing) and were due to embark on second year. Of the 12 students, one was female and the rest male. This roughly corresponds to the 1:9.2 ratio of respondents in the first phase of this study, which is also in line with the ratio of 1:9 female to male entrants each year in sessions 2010 onwards. The students were asked to avoid discussing their challenges with one another.

5.2. Coding the phrases received from students

Seventy-four different phrases were received from the 12 students. First stage coding analysis, sometimes known as open coding (Thornberg & Charmaz, 2014), was carried out as "a way of indexing or categorizing the text in order to establish a framework of thematic ideas about it" (Gibbs, 2007). Thematic coding is an analysis approach for qualitative data which involves reviewing that data and generating codes and themes allowing the opportunity to establish common themes and categories in the data (Mountain, 2015).

Coding involves naming segments of data with a label that “simultaneously categorizes, summarizes, and accounts for each piece of data” (Charmaz, 2006). In order to arrive at codes, emerging themes or concepts (explanatory ideas) closely linked in meaning are identified from the data in the first stages of analysis; these are given a label or code that describes them. Concepts were formed into categories: categories which have similar meanings were brought together into a theme. The 74 phrases were categorised under the following 30 labels:

Table 1: 74 phrases denoting challenges and difficulties coded into 30 labels

1	Catching up missed classes and material	16	Finding your way around
2	Fitting in with other students	17	Doing paid work alongside study
3	Working in groups with others not doing their fair share	18	Balancing university work and social life
4	Worrying about cost of living and money	19	Writing academic reports and essays
5	Acclimatising to a new study environment	20	Juggling several deadlines at once
6	Moving away from home	21	Preparing for classes beforehand
7	Figuring out inconsistencies between modules	22	Realising when to ask for help
8	Accommodating slower students	23	Staying motivated and focused on study*
9	Tolerating inconsiderate behaviour in classes	24	Getting on with people who are different from you
10	Feeling insignificant because only a first year	25	Putting in extra effort to get higher marks
11	Lacking experience in new projects	26	Homesickness
12	Studying at a higher academic level than previously	27	Being ill
13	Conveying technical information	28	Stressing about University
14	Programming and working with technology	29	Suffering loneliness
15	Managing time with classes spread across the week	30	Experiencing racial prejudice

* It was later recognised that the presence of “and” in the item “Staying motivated and focused on study” might cause ambiguity. Whilst there is no evidence from either the pilot and evaluation, or from administering the final questionnaire on two occasions, that respondents misunderstood the item or considered *motivation* and *focus on study* to be anything other than two dimensions of the same essential construct, it has been decided that this category will be modified in future versions of this instrument.

Like their source phrases, the 30 items reflect a wide range of themes, namely academic, classroom dynamics, social, financial, personal organisational, health, and existential.

5.3. Computer Science specific items

The students contributed only two CS-specific phrases to the original pool of 74, which were carried over unchanged into the 30 item version: “Programming and working with technology” and “Conveying technical information”. Given that the students surveyed were those who had met the requirement to pass the introductory programming module, it is to be expected that CS-related impediments feature less prominently. Further, the wording of the task was deliberately non-CS specific in order to gain a picture that reflected the breadth of students’ experience.

Arguably, a weakness of this method is the lack of the failed students’ perspective. Students take six modules per year, and must pass them all to proceed. Ten different modules are accessible to students; of these, three (introductory programming, computer systems, and introduction to HCI) are compulsory for all, and the rest are taken according to the various CS degrees. Three of the ten available modules are programming-intensive, and data drawn from failed students’ record of achievement showed that 29 of the 30 who could not proceed to year two failed at least one programming module, and eight of the 30 failed *only* programming modules. On the other hand, 22 students failed non-programming modules as well, so there is no guarantee that failed students would have cited difficulty with programming as their only block to progression, although it evidently played an important part.

For this reason, colleagues concerned at poor progression rates in their institutions would be recommended to examine the proportion of programming fails to failures in non-programming intensive modules, to help decide whether a self-efficacy test focusing on programming, such as Ramalingam & Wiedenbeck’s (1998), could be administered to beneficial effect alongside a first year experience instrument.

5.4. Achieving a usable number of items through item evaluation

The aim of this stage of development was to reduce the number of items to 20, to achieve a more manageable instrument that would maintain the interest and attention of students throughout, and was less likely to be answered automatically or abandoned part-way through. A 30 item questionnaire was constructed incorporating a six point agreement scale. We wanted to check that coding had been effective in removing duplicate issues; if we identified more than one statement that in effect described the same challenge, we could potentially re-code them and thus reduce the item count.

One option at this point was to survey the full cohort of 116 with the 30 item questionnaire and carry out a factor analysis on the responses to determine the least relevant. However, there was the risk that the response rate would be low, and also that this more involved method might lengthen the instrument’s development period past the key point to administer it, the start of the new academic year, before entrants had begun classes.

The other option was to continue with the original 10% sample who had contributed the 74 items, but add another set of students from the same first year CS population.

Figure 1: Rubric and first few items of evaluation questionnaire

Improving the First Year Self-Efficacy Scale

We asked 12 School of Computing students who had just finished first year to supply up to ten phrases representing challenges that they encountered during the academic year. The students provided 74 different phrases. By using a method called Open Coding, the 74 phrases were categorised under the 30 item labels below.

This questionnaire is designed to help us reduce the length of the self-efficacy instrument, by discarding the least relevant and realistic items.

To what extent do you agree that each phrase represents a **relevant and realistic, common challenge** you might face during first year. (Please tick one only)

1 Catching up missed classes and material
☐Strongly agree ☐Agree ☐ Slightly agree ☐Slightly disagree ☐Disagree ☐Strongly disagree

2 Fitting in with other students
☐Strongly agree ☐Agree ☐ Slightly agree ☐Slightly disagree ☐Disagree ☐Strongly disagree

3 Working in groups with others not doing their fair share
☐Strongly agree ☐Agree ☐ Slightly agree ☐Slightly disagree ☐Disagree ☐Strongly disagree

Of the set who contributed the 74 original items, 11 responded. A further 12 students from the same cohort who were coming fresh to the project were asked to complete the questionnaire, of whom ten responded, all male,giving a total of 21 participants in the item review stage, a sample of 17.7% of students who had passed the year, or 14.1% of those who had begun it.

The evaluation questionnaire gave explicit instructions on how to gauge the representativeness of the 30 individual items using the following phrase: “To what extent do you agree that each phrase represents a relevant and realistic, common challenge you might face during first year” in order to “help us reduce the length of the self-efficacy instrument, by discarding the least relevant and realistic items” (Figure 1). A six-point agreement scale was used to maximise response variance, without the option of a neutral response. Each of the 30 items was rated according to the average of 21 responses, the number of 6 scores and the number of 1 scores. The correlation matrix (Appendix 1) shows their responses to the six-point agreement scale.

To confirm that the coding stage had been effective and that the phrases were independent of one another, we examined every pair with a correlation of .7 or more, six pairs in total. For example, item 13 “Conveying technical information” and item 17 “Doing paid work alongside study” had the highest correlation at 0.77, and we decided that they were conceptually and semantically unrelated issues and that we could not discard either question. All six pairs turned out to be similarly distinct, so we could not use correlation as a reliable method for dropping items, therefore the items were then ranked in order of students’ evaluation of them as relevant and realistic, and the ten lowest ranking items were dropped.

Table 2: Items dropped from draft questionnaire to form final 20-item instrument

Item number	Text of item to be dropped

6	Moving away from home
8	Accommodating slower students
9	Tolerating inconsiderate behaviour in classes
10	Feeling insignificant because only a first year
16	Finding your way around
24	Getting on with people who are different from you
26	Homesickness
27	Being ill
29	Suffering loneliness
30	Experiencing racial prejudice

5.5. Rationale for study design

The intention was primarily to enable a number of stakeholders, for example, lecturers, guidance tutors and administrators, to gain a broad picture of the cohort's self-efficacy in relation to the 20 challenges in first year. The insights gained can raise awareness and help direct efforts to improve the first year experience for the next cohort. These extend beyond the academic's remit of syllabus and module content, to administrators improving timetabling to aid personal organisation and time management, while student support staff can enhance social, health and finance strategies aimed at the student body as a whole.

Another objective was to trial the questionnaire as a within-person measure of how much impact the endurance, enjoyment or simple experience of first year has had on each student's perception of their self-efficacy.

Lastly, it would be interesting to discover whether CS students' mindset regarding programming would have changed after experiencing it at university-level. Although they acknowledge that their research is not conclusive, Flanigan, Peteranetz, Shell, & Soh (2015) give thought to how CS students' implicit theories of intelligence (Dweck & Leggett, 1988) can change over the course of time. Bartimote-Aufflick et al (2016) cite performance accomplishments as the most potent sources of efficacy beliefs for university students, referring to "actual experiences of success and failure, with success experiences leading to increases in efficacy expectations and failure experiences leading to decreases in efficacy expectations".

5.6. Timing of survey

The resulting 20-item questionnaire was constructed in Novi for online completion, with a back-up paper copy, plus instructions and consent form. The scale used was the standard self-efficacy scale (Bandura, 2006), which emphasises that respondents should estimate their confidence "as of now", and which has been used in a large number of context-specific instruments. The better-known word "appraisal" was used in place of "self-efficacy" on the questionnaire.

It was administered at two time points in a single academic session: T1, the first morning of induction into the university (early September 2015) and T2, 10 weeks into the second university semester (mid-April 2016).

The questionnaire was first administered during induction week. Participants were given the URL for online completion; alongside the paper consent form, students were also given a paper questionnaire consisting of screen dumps from Novi as a back-up. This was fortuitous, as over 40 students experienced difficulty in accessing the questionnaire online.

Figure 2: Scale and first few items of final 20-item questionnaire

First Year Appraisal Questionnaire

Please rate how certain you are AS OF NOW that you can overcome the following challenges:

Rate your degree of confidence by recording a number from 0 to 10 using the scale given below:

0	1	2	3	4	5	6	7	8	9	10
	Cannot do at all				Moderately can do				Highly certain can do	

Catching up missed classes and material

0 1 2 3 4 5 6 7 8 9 10

Fitting in with other students

0 1 2 3 4 5 6 7 8 9 10

Working in groups with others not doing their fair share

0 1 2 3 4 5 6 7 8 9 10

6. Findings from initial analysis of questionnaire responses

At T1 during induction, 121 students responded online and 41 on paper; none responded by both methods. From 162, 156 usable T1 questionnaires were received of whom 17 or 11% were female, a 96.2% response rate, with the remainder lacking either identification or responses. An identical questionnaire was administered on paper to the same cohort of students, in a lecture common to the whole cohort, during week 10 of the second semester. By then, seven students had already withdrawn from the year, and 73 students attended that lecture, of whom 66 were from the original population. It was established that the other seven were not CS students and were beyond the scope of this study. Only the questionnaire's title was changed to include the word April, to distinguish them from T1 responses. All 73 students present completed the questionnaire; their matriculation numbers were matched to those of the T1 responses, and 66 matched pairs were identified. They formed 42.5% of the possible matched pairs.

6.1. Items with highest and lowest self-efficacy at T1 and T2

The 156 usable questionnaires received at T1 (first morning of induction) were input into an Excel spreadsheet. As with standard self-efficacy scales, individual scores ranged between 0 and 10, with 0 indicating least certainty of overcoming the challenge and low self-efficacy, and 10 indicating most certainty. All but 9 students answered all 20 items, and all gave a range of scores. Averaging the scores for each item indicate that at induction students are **highest** in self-efficacy and most certain of overcoming the following challenges:

Table 2: Items with highest self-efficacy scores at T1 (n=156)

	Question	Mean	Std Dev	Mode
1	Managing time with classes spread across the week	7.61	1.27	7
2	Putting in extra effort to get higher marks	7.56	1.51	8
3	Studying at a higher level	7.37	1.78	7
4	Programming	7.34	1.95	8
5	Conveying technical information	7.29	1.69	8

and **lowest** in self-efficacy regarding the following challenges:

Table 3: Items with lowest self-efficacy scores at T1 (n=156)

	Question	Mean	Std Dev	Mode
1	Writing academic reports and essays	5.98	1.85	6
2	Lacking experience in new projects	6.00	1.80	7
3	Stressing about University	6.24	2.32	8
4	Worrying about cost of living and money	6.48	2.59	8
5	Working in groups with others not doing their fair share	6.54	1.80	7

We can see from the item averages that across the cohort, students begin the year generally confident about their capacity to overcome a range of challenges. Even items about which students have the least confidence score positively above 5. The item with the lowest self-efficacy score at induction is "Writing academic reports and essays", echoing Rowan's observation (2015) that technical students have more difficulty with writing than students in the humanities; there is a marked contrast with "Conveying technical information", about which students are much more confident.

At T2, an initial analysis was undertaken of the 66 questionnaires whose matriculation numbers showed they belonged to students who had also answered at T1. Again, an average was taken of the scores for each of the 20 items. Of the 66 questionnaires, 57 scored all 20 items, eight scored 19 items, and one scored 18 items. Eight respondents or 12% were female.

We are particularly interested in the responses from these 66 respondents as, of the 156 students at induction, this is the group for whom we can measure changes in reported self-efficacy across the year, and attempt to argue for the impact that the first year experience has had on their confidence.

We find that at T2 students were **most** certain of overcoming the following challenges:

Table 4: Items with highest self-efficacy scores at T2 (n=66)

	Question	Mean	Std Dev	Mode
1	Studying at a higher academic level than previously	7.77	1.97	8
2	Acclimatising to a new study environment	7.59	1.86	8

3	Fitting in with other students	7.55	1.84	8
4	Programming	7.41	2.23	10
5	Managing time with classes spread across the week	7.35	1.95	8

and **lowest** in self-efficacy regarding the following challenges:

Table 5: Items with lowest self-efficacy scores at T2 (n=66)

	Question	**Mean**	**Std Dev**	**Mode**
1	Lacking experience in new projects	6.12	2.31	8
2	Stressing about University	6.15	2.76	7
3	Preparing for classes beforehand	6.32	2.16	7
4	Worrying about cost of living and money	6.40	2.26	7
5	Working in groups with others not doing their fair share	6.45	2.37	8

It is worth pausing to describe the 66 students: they have persisted with their studies, and display organisation, time management and motivation enough to be sitting in a lecture relatively late in the second semester.

A pair-wise t-test was applied to the results from the two surveys (see Table 7). Responses indicate they have gained in confidence about writing reports and essays, perhaps because of a course in academic literacy most have undertaken during the first semester. However, surprisingly, despite a year on their course, students have scarcely improved in confidence in overcoming their lack of experience in new projects, and four out of the five items with the lowest self-efficacy scores are unchanged. “Preparing for classes beforehand” tumbles from 7.43 to 6.39, a significant drop ($p<0.01$) from T1 to T2, indicating, perhaps, a more realistic assessment of competing demands on their time. This is echoed to some extent in the lowering of this sample’s confidence in “managing time”, significant at $p<0.05$.

Table 6: Change in self-efficacy of 20 items between T1 and T2, average based on 66 responses

	catching up	fitting in	working in groups	worrying about money	acclimatising	figuring out modules	lacking experience	studying at higher level	conveying tech info	programming	managing time	paid/study	balancing work/social	writing reports	juggling deadlines	preparing for classes	ask for help	extra effort	staying motivated	stressing
2015 Sept	7.56	7.45	6.62	6.95	7.70	6.81	6.21	7.84	7.83	8.02	7.98	7.26	7.57	6.84	7.05	7.43	7.30	8.10	7.92	6.62
2016 April	7.18	7.54	6.55	6.69	7.58	7.09	6.11	7.77	7.17	7.40	7.32	7.02	7.29	7.13	6.45	6.39	6.62	7.32	6.49	6.30
Change	-0.37	0.09	-0.07	-0.26	-0.11	0.28	-0.10	-0.07	-0.65	-0.62	-0.66	-0.24	-0.28	0.28	-0.59	-1.04	-0.69	-0.77	-1.43	-0.32
Significant at p<0.01									TRUE							TRUE		TRUE	TRUE	
Cohen's d									0.40							0.53		0.47	0.74	

In table 7, the confidence interval was around 0.6 for most questions. Taken as a whole, figures show a loss of confidence for all but three of the 20 items. The starkest change appears to be these students’ confidence in staying motivated, where the effect size is 0.74 – Cohen's d is "large" at 0.8 and "medium" at 0.55 (Cohen, 1988). Despite being the group who, by virtue of being in the lecture at T2, are more reflective of persistence and conscientiousness, they show the steepest drop, significant at $p<0.01$, in confidence in their ability to stay motivated.

It could be argued that the decreases are exaggerated because T1 scores reflect over-confident entrants (Sobel, Gilmartin, & Sankar, 2016) (Allan, Mckenna, & Dominey, 2014); 88% of the sample was male and Allen et al. (2014) find that that this is characteristic of male students at the outset of their studies. They might have come from families, schools or FE colleges where they were the best amongst their peers, and their T2 drop in confidence might reflect a realistic assessment of their capabilities on finding their place in the larger cohort and experiencing the day-to-day challenges of university life. It is also possible that a dramatic lowering in motivation self-efficacy can affect the way students report their confidence in meeting other challenges, including programming.

Similarly, contextual factors at T2, such as apprehensiveness at impending end-of-semester assessments or the accumulation of minor challenges (Collie, et al., 2017) might also depress scores.

6.2. Change in programming self-efficacy between T1 and T2 in matched responses

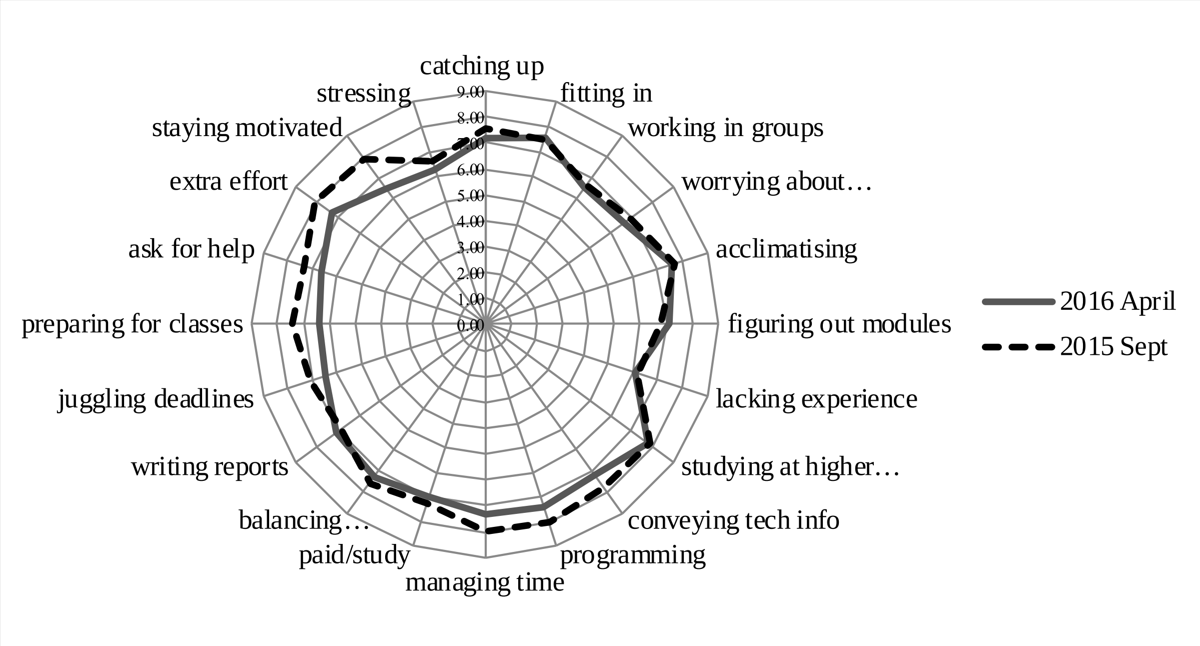
Only two items, "Conveying technical information" and "Programming" could be characterised as specific to Computer Science. Their relative unimportance to the students who originally contributed the items contrasts with our observation, reported in section 5.3, that a failure in a programming module in their cohort was a near-universal factor in non-progression. Between T1 and T2, this sample shows a drop from 7.83 to 7.17, significant at $p<0.01$, in confidence in conveying technical information.

Although "Programming" enjoys a positive score of 7.40 at T2, this masks a troubling drop in confidence since T1, when the 66 students in the T2 sample scored it at 8.02, significantly ($p<0.05$) higher than the average score across all items for the T1 sample of 156, and the second highest item score after "Putting in extra effort to get higher marks" (see Table 7). Our finding therefore is that students start out with very high self-efficacy in programming, which drops over the course of first year. This seems to bear out Ramalingam and Wiedenbeck's finding (1998) of a general increase in self-efficacy on their post-instruction measure, but with the greatest gains seen in those with lower initial self-efficacy scores.

By T2, these students have undertaken and should have passed at least two, and commonly three, programming assignments, yet, echoing Kinnunen & Simon's findings (2012), they reflect negative views of their efficacy. As Bartimote-Aufflick et al remind us (2016), a failure in performance in any of these assignments could lead to a decrease in efficacy expectations, the flip side to Collie et al.'s point that when students have a positive experience such as successfully navigating a challenge or gaining a high mark, this is related to a greater sense of control over future academic outcomes (2017).

This raises questions about students' perceptions of the programming that they have undertaken, whether simply *passing* programming modules is sufficient to maintain confidence, and whether the *experience* of programming in the university environment is detrimental to at least some students' confidence.

Figure 3: Difference in item averages between T1 and T2 (n=66)



7. Implications of findings for self-efficacy instrument deployment and for practice

Administering this questionnaire has been straightforward, and students take about six minutes to complete it, minimising disruption to a teaching event. There were relatively few incomplete or unusable questionnaires at T1; at least two can be attributed to inability to access the questionnaire properly online, which is why T2 was paper-only, helping to eliminate unusable papers. However, students' tendency to disengage and absent themselves from activities at which data collection can take place forms a considerable impediment to measuring an individual student's T2 self-efficacy against final achievement. Without a large sample of students completing both stages of data gathering, findings are so tentative, that no meaningful indicators of students' buoyancy and persistence into second year can be gleaned.

Instead, we can report that the greatest benefit arising from both the investigation of the literature and the trial run of this instrument, has been to give CS course leaders insights into loss of confidence in ability to overcome challenges in programming and in staying motivated. We have recognised the dynamic of CS tutors of large classes directing their teaching towards the students they presume are enthusiasts who have greater programming experience (Ulriksen, Madsen, & Holmegaard, 2015). We have acknowledged the risk that a body of potentially apt and capable programmers may be less catered for. In labs, their confidence may be being lowered when they compare themselves unfavourably with the enthusiasts (Kinnunen, Marttila-Kontio, & Pesonen, 2013), and we may thereby be unwittingly exacerbating their demotivation. The danger is that an early dent in self-efficacy may cause a negative feedback loop and drive students towards failure (Lishinski, Yadav, Good, & Enbody, 2016).

Following this pilot, we have therefore split the introductory programming module's class in two, separating those on the more programming-intensive courses which require higher entry qualifications, to which enthusiasts are more likely to be attracted (Sobel, Gilmartin, & Sankar, 2016). Whilst the aim of the course remains to introduce all CS students to Java and give them a good practical grounding in writing code, it now takes into account the differing starting points amongst students and allows greater support in their own labs for the non-hobby programmers.

7.1. Further work

There are several ways in which this work could be extended: one is to attempt another way of eliciting the experience of those who failed their first year and updating the item list. Another is to administer this first year experience instrument alongside another, such as Ramalingam & Wiedenbeck’s more programming-specific scales (1998).

With this study’s relatively small sample of 66, it hasn’t been possible to make supportable links between an individual student’s self-efficacy scores in programming or any other item and his/her academic achievement at the end of the year. A larger sample might also yield enough female participants to allow a gender-focused analysis. Therefore, at time of writing, a university in northern England and one in northern Scotland have implemented the questionnaire in their Computer Science departments, with a view to pooling data in the hope of finding a relationship between either T1 or T2 and performance, but mainly to find insights for themselves into reasons for non-persistence amongst their CS first years.

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