Female pupils' attitudes to computing in early adolescence

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ABSTRACT

Female students are under-represented in optional Computer Science qualifications in England's schools. We know that educational and career choices are affected by students' attitudes towards the subject and perceptions of their own ability, as well as societal factors. In the current study, a validated survey was adapted and administered to 960 pupils in 7th Grade (age 12-13; 788 female) and 356 pupils in 5th Grade (age 10-11; 171 female). The survey comprised five scales concerning attitudes towards computing: confidence, interest, feelings of belonging, perceptions of usefulness of the subject, and feelings of encouragement to take the subject. Higher scores represent more positive attitudes. We found a significant difference between female and male pupils, with females scoring lower across all scales of the survey in both year groups. Female pupils in mixed-sex high schools reported lower scores for feelings of belonging compared to those in single-sex schools (a statistically significant difference), but did not differ for any of the other scales. These results suggest that less positive attitudes towards computing are evident in female pupils early in their education, and may be associated with differences in their school environment. This is likely to affect their later engagement with computing and choice of optional Computer Science qualifications. Early interventions focusing on confidence, attitudes and perceptions are therefore of great importance in increasing the representation of female pupils in Computer Science.

CCS CONCEPTS

• **Social and professional topics** → **K-12 education**; **Gender**.

KEYWORDS

attitudes, belonging, gender, identity, K-12 computing education, perceptions

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1 INTRODUCTION

Computer Science (CS), alongside other Science, Technology, Engineering and Maths (STEM) disciplines, is largely male-dominated. Although the lack of gender balance has been identified, there is relatively little strong evidence regarding successful interventions to address this issue. A better understanding is required of the potential barriers to female engagement with computing from an early age.

In the English education system, computing is a mandatory part of the curriculum throughout primary and high school. Pupils usually attend primary school until 5th Grade (age 11) and then move to high school. High schools are split into mixed-sex (co-educational) or single-sex settings. For the current study, 5th Grade pupils from 10 primary schools and 7th Grade pupils from 13 high schools completed a survey on their attitudes towards computing as part of a pilot study investigating different teaching methods to engage more girls in the subject. Analyses addressed the following research questions:

- Is there a gender difference in attitudes towards computing?
- Do female pupils attending mixed-sex or single-sex schools differ in their attitudes towards computing?

The next section provides an overview of the gender imbalance in Computer Science (CS). We will introduce theories relating to identity and self-efficacy as well as the framework of *expectancy-value theory* for understanding how females' attitudes and beliefs relate to educational and career choices. We will also consider the effect of single-sex groups on females' performance and attitudes. The rest of the paper will describe the survey and participants before presenting the results and considering their implications for future interventions.

2 BACKGROUND

2.1 Gender imbalance in Computer Science

In 2017, only 10-20 percent of pupils choosing optional CS courses in English high schools were female [16]. While there has been a gradual increase in undergraduates choosing CS degrees between 2016 and 2019, the proportion of female students has remained stable at around 17-18 percent in English universities [1]. The 'Women in Digital' scoreboard published by the European Commission highlights that around 17.5 percent of technology specialists in the UK workforce are female, reflecting a similar pattern across Europe [6]. Understanding the factors that are discouraging females from specialising in computing is of great importance to help balance the gender profile within the technology sector.

The relatively low percentage of females choosing computing qualifications and careers does not seem to be the result of a lack of aptitude for the subject, given that female students tend to outperform their male counterparts in formal computing assessments in high school [16]. Rather, there seem to be gender differences in students' attitudes towards computing. These attitudes are the evaluative judgements that students make about a subject based on a number of factors, including their own prior experiences [18].They can relate to students' perceptions of their own identity and how this fits within computing, their feelings of confidence in their own abilities in the subject, and their perceptions of how others value the subject, and whether it will be of use in future careers [5, 7]. We will now discuss these factors in more detail.

2.2 Female students' computing identity and self-efficacy

Identity is a multifaceted construct that interacts with social structures and situations to produce a range of possible 'selves' that can be enacted during social interactions [4]. The prominence of a particular identity refers to the value that an individual attributes to it, i.e., how invested they are in that particular role or representation of themselves to others [25].

According to Ervin and Stryker, identity theory is also tightly linked with an individual's self-efficacy [11]. Self-efficacy forms part of a wider construct of self-esteem, which is defined as an individual's evaluation of their own value and worth [22]. Self-efficacy is an individual's evaluation of their ability to control aspects of their own lives (global self-efficacy) or particular tasks in specific contexts (specific self-efficacy) [3]. If a female student has high confidence in her ability to perform tasks in a specific situation (e.g. successfully complete computing tasks in the classroom), she is more likely to value and therefore enact the identity that relates to that task and situation. This suggests that supporting female students in their development of self-efficacy beliefs, or confidence, is therefore of great importance in promoting a strong sense of identity in computing or a feeling of belonging to the discipline. Indeed, a feeling of belonging and being part of a wider community is a key factor in female students' motivation to study computing [20].

Self-efficacy can be influenced by a number of different factors and may lead to a range of life outcomes [2]. Those with low self-efficacy are likely to anticipate poor results when faced with a challenging task, believe that they are unable to cope with the demands of situations, and will not be motivated to set themselves goals that will stretch their abilities. Supporting female students in their development of strong self-efficacy beliefs is therefore of great importance, for example through providing opportunities for success in a particular task, or through giving positive feedback and encouragement [2]. Strong self-efficacy and computing identity, along with social encouragement and support, will be key to increasing the number of students choosing computing as a subject and career [10]. These factors are considered further in the next section.

2.3 Expectancy-value theory

Eccles et al. proposed the *expectancy-value model* to explain students' educational and career choices based on a range of psychological and social factors [10]. Specifically, the model highlights the individual's own beliefs about their ability and their likelihood of success in a particular field, as well as the value placed by the individual on particular subjects or careers, as important psychological factors. Social factors include the beliefs and actions of parents, teachers and peers, as well as societal expectations of different gender roles.

This model has been applied to understand gender differences in STEM career choices as a whole [27] and in CS in particular [9, 19]. Computing courses were less likely to be chosen by female students than male students from as early as 5th Grade [9] and this lower participation was influenced by reduced feelings of belonging [19], lower expectations of success, lower perceptions of the value of the course, and lower perceptions of parents' valuing of the course [9] by female students compared to male students. However, these studies recruited participants from one or two schools, with fewer than 100 female students in each sample. The current research aimed to investigate these potential gender differences in a larger sample across a wider range of schools in order to assess their validity in an English context.

Understanding the different factors and how they affect female pupils in specific contexts can help identify potential interventions to improve uptake of computing qualifications and careers. For example, Denner et al. used the expectancy-value model as the basis of an after-school and summer computing programme which targeted middle-school Latina girls' interest and feelings of belonging in computing, their belief in their own ability, and their perceptions of social support from parents, teachers and peers [8]. The programme had promising results, with students showing increased interest in computing careers, as well as higher expectations of their own success in computing.

2.4 The effect of all-female groups

Like the study by Denner and colleagues [8], out-of-school interventions often focus on building a community of female students and helping to develop a network of like-minded people from similar backgrounds to support each other within computing [23, 26]. It is therefore important to consider to what extent attitudes towards computing are associated with the peer group and environment in which students are learning computing.

Previous studies have suggested that the decoration of computing classrooms may be biased towards stereotypically male interests [19] and that male students may tend to dominate unstructured discussion in the computing classroom [12]. Creating female-only environments may therefore improve female students' experience of computing and help to develop a feeling of belonging. Indeed, there is evidence that girls in single-sex schools are more likely to choose to study CS than those in mixed-sex schools [17] and so it is important to understand why these differences emerge in subject choice, and how it may be affected by a number of individual and school factors. Given the influence of peers [8] and the impact of gender stereotypes on female students' attitudes to computing [19], it is possible that differences in the peers around them could be associated with female pupils' attitudes towards computing.

Although research on the benefits of single-sex schooling on STEM-related attitudes is mixed [27], a meta-analysis has been conducted on students' performance and attitudes across mathematics and science, as well as more general educational aspirations, self-concept, and gender stereotyping, in 184 studies of K-12 students across 21 nations [21]. The detailed analyses revealed very small or no differences in the outcome measures between those attending single-sex or mixed-sex schools. The authors highlighted that many of the studies that did find positive effects for single-sex schooling were poorly controlled, and argued that there was therefore no strong evidence for the benefits of single-sex schooling. Although the meta-analysis did not focus on computing specifically, it suggests that taking a broader overview of the literature rather than a focus on individual studies and interventions could provide a clearer idea as to the benefits of teaching computing in single-sex groups on females' attitudes towards computing and their continuing participation in the discipline.

2.5 The current study

The current study extends previous investigations to an English context, investigating attitudes towards computing in students between the ages of 10 and 13 in a larger sample than recruited in previous studies on this topic [9, 19]. Specifically, we focused on aspects of students' attitudes that have been identified in previous research as important for future educational and career choices in STEM, and in computing specifically: students' confidence in their own ability, interest in the subject, and perceptions of the use of computing in the future (psychological factors), as well as feelings of belonging and perceptions of encouragement from those around them (social factors). Based on previous research, it was expected that female students would have lower scores on measures of all of these factors compared to male students. We also compared the attitudes of females in different social environments, namely those in mixed-sex or single-sex schools. Based on previous research, however, it is unclear whether attitudes towards computing would differ between female pupils in single-sex and mixed-sex schooling.

3 METHOD

3.1 Participants

3.1.1 School recruitment. Eleven primary schools and fifteen high schools volunteered to participate in the study. The study was advertised to teachers who had expressed an interest in participating by responding to a blog post, adverts on social media, or through computing teacher networks. More information about the project, including the teachers' and pupils' involvement, was provided, and agreement was obtained from Headteachers to participate in the study. One or two teachers from each school attended a training day to introduce the study, including the survey measure reported here. One primary school and three high schools were unable to continue with the study due to other commitments. In the final sample, there were 10 primary schools (2 independent; 8 state-funded; all mixed-sex), of which 9 were in urban locations. The number of pupils eligible for free school meals ranged from 6.4% to 60.1% in the state-funded schools. There were 12 high schools (3 independent, of which 2 were single-sex and 1 mixed-sex; 9 state-funded, of which 4 were single-sex and 5 mixed-sex). Of the 12 schools, 9 were in urban locations. The number of pupils eligible for free school meals ranged from 5.5% to 31.8% in the state-funded schools.

Table 1: Number of male and female participants from single-sex and mixed-sex schools in 5th and 7th grades

Grade	Female	Male	Pupils in each Grade
5th	171	185	356
7th mixed-sex	202	172	960
7th single-sex	586		
TOTAL	959	357	1316

3.1.2 Pupil recruitment. Teachers identified a minimum of one class in their school with which to run the study: primary schools focused on pupils in 5th Grade (Year 6 in England; age 10-11), and high schools focused on 7th Grade (Year 8 in England; age 12-13). In line with the British Educational Research Association ethical guidelines, the research team provided an information letter and privacy notice to be sent out to parents/carers of pupils in the selected class or classes, informing them of the nature of the project, the data that would be collected about their child, and how that data would be processed. Pupils and parents were given the opportunity to opt out of data collection, and were informed of their right to withdraw their data up to the point of analysis and evaluation.

In total, 1395 pupils completed the survey (382 5th Grade; 1012 7th Grade). Of this number, 14 5th Grade and 40 7th Grade pupils identified their gender as neither male nor female (either choosing 'a different gender' or 'prefer not to say'). Given that the numbers in these groups were too small to include in group comparisons for the current study, only those pupils who identified as male or female were included in the analyses. An additional 24 pupils were removed from the sample (5th Grade: 6 female, 6 male; 7th Grade 10 female, 2 male) due to surveys being incomplete. Details of the final sample are presented in Table 1.

3.2 Survey

The Student Computer Science Attitude Survey [14] is a validated questionnaire designed for students aged 13 and over which addresses five key constructs:

- Students' *confidence* in their ability to learn CS skills and solve CS problems
- Students' *interest* in learning computer science and solving problems
- Students' perceptions of *belonging* in CS
- Students' beliefs in the *usefulness* of learning CS
- Students' perceptions of *encouragement* to study CS

Each scale consists of five statements to which students respond on a 4-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree, resulting in a potential range of scores of 5-20 for each scale. The total score for each scale was used in the current analyses, with higher scores representing more positive attitudes.

For the current study, the questionnaire was adapted (with the authors' permission) for use with primary school children and digitised so that data could be collected online. Survey items were assessed for readability at a primary school level and adapted where necessary (i.e. "I would take additional computer science courses if I were given the opportunity" was changed to "I would take more computing lessons if I could" in the 'Interest' scale). Examples of each of the other scales include: "I am good at learning computing skills on my own" (Confidence); "I know someone like me who uses computing in their work" (Belonging); "I will need very good computing skills for my future job" (Usefulness); "Someone in my family has made me want to learn computing" (Encouragement).

The adapted survey was used across both younger and older age groups. Cronbach's alpha for each of the scales in the current study were as follows: Confidence = .87, Interest = .84, Belonging = .73, Usefulness = .84, Encouragement = .82. In addition to the SCSAS scales, students recorded their names, gender (from a drop-down menu consisting of four options: male, female, other gender, prefer not to say), date of birth, school name and school town. Once information concerning school type and gender were coded for analysis, all identifying information was removed so that data were anonymised.

3.3 Procedure

Teachers were provided with project guides which explained how to administer the survey. Teachers were asked to explain to their pupils the purpose of the surveys, as well as the pupils' rights to opt out and to withdraw their data up to the point of analysis and evaluation. Pupils were then provided with a link to the electronic survey to complete individually. Teachers were permitted to provide assistance in reading or understanding the questions where necessary, but were asked to ensure that pupils responded individually. The research team accessed the data electronically, coded it and anonymised it ready for analysis.

3.4 Statistical analyses

To assess whether a gender difference was evident in attitudes towards computing (Research Question 1), a Multivariate Analysis of Variance (MANOVA) was conducted on the mean SCSAS scores, with Gender and Grade as independent variables, and the five SCSAS scales as the dependent variables. The Box test revealed that the assumption of homogeneity of covariance was not met (p<.001) and so non-parametric Mann-Whitney tests were also conducted comparing males and females across year groups, corrected for multiple comparisons. Given that the same pattern of results was revealed using the parametric and non-parametric tests, the results of the MANOVA are presented below. Planned univariate ANOVAs on each of the SCSAS scales were then conducted. Bonferroni correction was not applied to these follow-up analyses due to the small number of a priori hypotheses being tested [24].

To assess whether female pupils' attitudes towards computing differed between those attending a mixed-sex or single-sex school (Research Question 2), a second MANOVA was conducted on the mean SCSAS scores for 7th Grade female pupils only (no 5th Grade pupils attended single-sex schools). School social environment (mixed- or single-sex) was the independent variable and the five SCSAS scales were the dependent variables. All assumptions were met for these analyses. Again, planned univariate ANOVAs were conducted on each of the SCSAS scales to identify any gender differences on specific subscales.

4 RESULTS

4.1 Gender differences in attitudes towards computing

As presented in Table 2, female pupils tended to score lower on all SCSAS scales than male pupils in both 5th and 7th Grades, and younger pupils scored higher than older pupils. Using Pilliai's trace, there was a significant difference between Genders, V = .05, F(5,1308) = 12.82, p <.001, and Grades, V = .06, F(5,1308) = 17.78, p <.001, on attitudes towards computing, but no significant interaction between Gender and Grade, V = .01, F(5,1308) = 1.95, p =.08. Univariate ANOVAs conducted on each SCSAS scale revealed that these between-subjects differences were evident for all scales (Gender: Fs > 42.62, ps < .001; Grade: Fs > 47.71, ps < .001; Gender x Grade: Fs < 3.25, ps > .20).

4.2 Differences between female pupils' attitudes towards computing in single-sex and mixed-sex schools

Table 2 also presents the mean scores on the five scales of the SCSAS for female 7th Grade pupils in mixed-sex (n=202) and single-sex (n=586) schools. Using Pillai's trace, there was no significant overall difference in female pupils' attitudes towards computing between school social environments, V = .01, F(5,782) = 1.61, p =.16. The planned univariate ANOVAs conducted on each SCSAS scale revealed a small but significant difference between school types on feelings of belonging only, F(1,786) = 4.09, p = .04, with female pupils in mixed-sex schools reporting lower levels of belonging in computing compared to their counterparts in single-sex schools. All other scales did not differ between school types (Fs < 2.93, ps > .09).

5 DISCUSSION

The current study aimed to extend previous research on females' attitudes towards CS to an English school context, considering both psychological and social factors that may influence students' educational and career choices. Compared to male pupils, females reported lower confidence in their own ability, lower interest in the subject, as well as more negative perceptions of the use of the subject for their futures, their sense of belonging in the subject, and the amount of encouragement they received from those around them. These differences were all significant, and, importantly, were evident as early as 5th Grade in the current sample. Females' sense of belonging in the subject also differed between school types, with those attending mixed-sex high schools feeling less like they belong in computing than those in single-sex schools. We will now consider each of our research questions in turn.

5.1 Is there a gender difference in attitudes towards computing?

Our findings support previous research identifying a gender difference in attitudes towards STEM subjects in general [27] and in CS in particular [8, 9, 19], and fits with the range of psychological and social factors identified by the expectancy-value model [10] that may affect educational and career choices. In England, students elect whether to continue with formal Computer Science

Table 2: Mean total scores (and standard deviations) on the Student Computer Science Attitude Survey for male and female pupils in 5th and 7th grades

	SCAS Scale				
	Confidence	Interest	Belonging	Usefulness	Encouragement
5th Grade					
Male	14.92 (3.30)*	14.80 (3.28)*	14.43 (3.38)*	14.52 (3.40)*	14.92 (3.46)*
Female	13.75 (2.89)	13.62 (2.91)	13.15 (2.99)	13.12 (3.08)	13.39 (3.34)
7th Grade					
Male	13.67 (3.35)*	13.42 (3.36)*	13.13 (3.44)*	13.1 (3.63)*	13.12 (3.70)*
Female	12.08 (3.07)	11.76 (2.95)	11.32 (2.96)	11.16 (2.97)	11.35 (3.11)
Single-sex	12.19 (3.14)	11.86 (3.02)	11.45 (3.00)*	11.25 (3.02)	11.45 (3.15)
Mixed-sex	11.77 (2.82)	11.45 (2.72)	10.96 (2.79)	10.89 (2.83)	11.03 (3.00)

*significant difference between total scores

qualifications from 8th Grade (Year 9), so the current study does not provide insight into whether the more negative attitudes towards computing reported by females compared to males will affect their later subject choices. However, it seems likely, based on the wide range of evidence supporting the expectancy-value model across disciplines, that this will be the case [28]. The current results are important in identifying a number of specific areas from the survey in which educators and club leaders could intervene to improve females' attitudes towards computing, highlighting that this should be done as early as 5th Grade. For example, interventions may focus on social factors by working with parents and teachers to provide *encouragement* in computing from an early age, or by introducing role models and setting up peer-support groups to increase students' feelings of *belonging* to the discipline. Individual factors that were assessed in the current study and may be key for intervention include increasing students' *confidence* and *interest* in computing, as well as their perceptions of its *use* or value to their futures. Given that female students reported lower scores on all of these areas compared to male students, it will be important for interventions to be multifaceted and to consider the interactions between different factors that affect attitudes towards computing. Future research using a longitudinal design will also be necessary to assess the extent to which the gender differences in attitudes towards computing do impact take-up of the subject in formal qualifications.

In the current study, a greater proportion of the sample were in 7th Grade compared to 5th Grade, which was due to the increased number of classes and pupils in high schools within each grade compared to primary schools. It is possible that this could have driven the findings of a gender difference in attitudes if we expect that females' attitudes may become more negative as students get older. However, previous research has identified gender differences in attitudes to computing as early as 5th Grade [9]. Furthermore, the lack of a significant interaction between gender and grade in our own data suggests that the pattern of more negative attitudes in female pupils is similar across age groups. An important area of future research will be to identify how early this difference is evident, especially in England, where computing is mandatory from the beginning of school. This will identify key times at which intervention is likely to be most beneficial in terms of maintaining positive attitudes towards the subject.

5.2 Do female pupils attending mixed-sex or single-sex schools differ in their attitudes towards computing?

In terms of school social environment, there are mixed findings in the previous literature concerning whether there is a difference in female pupils' STEM-related attitudes in single-sex and mixed-sex schools [27] and no strong evidence for a benefit of single-sex schooling on performance and attitudes [21]. In the current study, it is of interest that only feelings of belonging differed significantly between the single-sex and mixed-sex environments. Previous research has suggested that gender stereotypes can have a negative effect on females' sense of belonging in computing and that this can reduce female pupils' interest in it as a subject or career [19]. It may be that females in a mixed-sex school see more examples of the male-dominated stereotype of computing compared to those in single-sex schools, which affects their sense of belonging in the subject.

Although female pupils in mixed- and single-sex schools in our analysis did not differ on the Confidence scale, it might be that females in mixed classes underestimate their skills compared to their male counterparts [15]. Teachers have suggested that being in a class with other students who have more experience of computing and use jargon or difficult terminology can affect less experienced students' self-efficacy, and this could be the case for females in mixed classrooms [13]. This may then affect female students' feelings of belonging, or the development of a strong computing identity [11]. However, it is not possible from the current survey data to infer that the school social environment *caused* the differences reported by female students in their feelings of belonging to computing, and there may be other individual differences between pupils attending single- and mixed-sex schools that we were unable to control in the current study. School variables such as percent of students eligible for free school meals, or independent vs. state-funded status may also be associated with differences in attitudes, but the relatively limited number of schools included in the current sample mean that it is not possible to assess these associations. It will be important for future research to investigate the different individual and school factors that could be associated with females' attitudes towards computing in single-sex and mixed-sex classes in a wider range of schools so that complex interactions between variables can be assessed.

In the current study, a greater proportion of the sample was female than male and this was due to the inclusion of a high number of single-sex girls' schools. No single-sex boys' schools were included because of the nature of the pilot project of which this survey was a part. It will be important for future research to focus more specifically on the impact of single- vs. mixed-sex schooling for both males and females on their experiences of and attitudes towards computing. This will not only improve our understanding of computing in the classroom, but will also help to design and evaluate out-of-school programmes aiming to develop computing skills and positive attitudes amongst underrepresented groups. It will also be important to understand the experiences of those who do not identify with binary gender descriptions, as we found for a proportion of our original sample, and to take a more intersectional approach to investigating attitudes amongst young people towards computing.

5.3 Conclusion

The current study investigated gender differences in attitudes towards computing across a number of psychological and social domains in a sample of over 1000 students from a range of primary and high schools. Female students between the ages of 10 and 13 reported more negative attitudes towards computing than their male counterparts. The data suggest that it may be important to consider the social environment of females in computing classes and clubs when evaluating research into female attitudes towards computing, and when designing interventions to engage more girls in the subject. Further research should be conducted to unpick the experiences of students in mixed- and single-sex computing groups to help us better understand the different factors affecting females' feelings of belonging and its impact on their educational choices, which will be vital in rebalancing the gender profile in computing qualifications and careers.

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