Gender Differences in Psychosocial Experiences with Humanoid Robots, Programming, And Mathematics Course

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Abstract.
Introduction: There is a gender imbalance in Computer science (CS) and STEM education and careers where males are more represented. With evolving technologies arising and the need for a more diverse workforce, it is important to identify factors that may cause females to be more prone to not persist in CS careers. This study investigated gender differences and psychosocial perceptions of experiences in a CS education class.
Method: Twelve students were recruited to the study. Data on judgements of performance and psychosocial aspects of the course was collected (learning, difficulty, enjoyment).
Results: There were no significant differences between boys' and girls' perceptions of performance and experiences in the course. Females, however, reported small to medium effect sizes in experiencing more learning, more enjoyment and experienced more difficulties than boys in the course.
Conclusion: Future studies should control for gender differences in CS and STEM education. Same sex role models might influence experience and perceptions of performance, which can influence persistence of females in CS careers.

Keywords: Gender differences, Computer Science, Human-Robot Interaction, Psychosocial Perception, Metacognitive Assessment, preadolescent students.

1 Introduction

There is a gender imbalance within computer science (CS). For instance, within major companies such as Google, Facebook and Twitter females comprise less than 20% of the workforce [1] and this is usually attributed to labor supply and demands. Despite this imbalance, recent research shows that females in CS education are similar to males in their cognitive styles and abilities [2] but their self-perception of their abilities may lead to different career choices. Females in CS education report better verbal fluency and artistic abilities than males, however with poorer self-assessment in academic achievement and leadership abilities [3]. Research has identified several cultural aspects that can explain the low representation. For instance, gender-role-modelling, community acceptance, and institutional support moderated participation and performance of females in CS [2, 4]. Further, females studying CS who had access to female role models in the field, and had instructors and institutions that encouraged and supported female representation, reported less negative stereotypical perceptions of themselves [4], showed greater adherence and completion of their studies, and outperformed their male counterparts [2]. Due to the gender imbalance in CS, female students are encouraged to choose educational programs within science, technology, engineering and mathematics (STEM) (see for instance https://www.sheffield.ac.uk/dcs/about-department/women-computer-science). This gender imbalance gives reason to assume that early influence, as in educational institutions, play a gender-specific role for later career choice. For this reason, the current project addresses preadolescent boys' and girls' experience on STEM – specifically programming, mathematics, and human-robot interactions – in education, including the experienced difficulty, enjoyment, and gains in learning.

1.1 Psychological Factors in Programming, Mathematics And Human-Robot Interactions

Being part of CS, a rapidly growing branch in technology is within robotics, which is gaining ever-expanding functions in society [5]. For example, robots have been implemented in school in functions as independent teachers, teaching assistants [6], classmates, peers, entertainers [7], support for children with special needs [8] and as a mediators for increased experience of presence in school for homebound children [9]. When the function of such robots is to interact with humans, they are designed to resemble and behave more like humans, so that a human-robot interaction (HRI) is possible [6]. Research shows that such robots can support development within areas including language, argumentation and discussion skills, problem solving, self-regulation, and building of relationships [6, 7, 10]. Unlike interactions with the teacher, the student may experience a more balanced dialogue when interacting with a robot, which to some students may involve less anxiety and embarrassment. This in turn may result in students daring to take chances in their thinking, coming up with ideas, and solving problems [6].

Robots can assist the teacher in following up individual students [7] which may provide several benefits, including development of self-regulated learning skills such as self-assessment, goal-setting, and the execution of strategies within a metacognitive process, which correlates highly with academic achievement [11]. Metacognition is understood as a representation of cognition, with the functions of monitoring and control, for instance planning, evaluation, and knowledge of what one knows and does not know [12]. According to Zimmerman [13] such self-regulated learning is associated with active participation in one's own learning process, involving the use of strategies within metacognition, motivational processes (e.g., self-efficacy), and behavior (e.g., optimizing one's learning environments). Jones and Castellano [11] suggest that social robots can be used to support the development of such skills which furthermore have the potential to be transferred to long-term behavior change, with a generalizing effect to contexts outside the classroom. However, such social robots may also have a distracting effect, thus influencing the students' attention and cognitive performance negatively [14]. Robots may nevertheless enable new ways of learning and teaching, and the presence of such social robots in teaching can prepare children for an everyday life which, independent of robots, is characterized by advanced technology [6].

1.2 Social Aspects in Programming, Mathematics And Human-Robot Interactions

When implementing a social robot into an educational setting, the students' social interaction (e.g., smiles, eye contact) with the robot have been found to vary. This may be due to variations in the robot's 'wow-factor' with a possible distracting effect [15], or due to variations in the students' level of internalized self-regulation and thus reliance on the robot to master the task [11]. For technology to have a supportive function in the child's development the child should be involved and engaged and the technology should promote a strong language model [16]. Varied and tailored feedback from social robots in education has been found to support and increase children's self-confidence and mastery. For example, Ahmad and colleagues [15] found that emotionally tailored feedback from the robot maintained the students' social engagement when positive, but not when feedback was negative or neutral. However, the researchers also found a preference for negative feedback compared to neutral feedback, possibly meaning that in some situations, criticism may increase motivation and focus, which in turn may contribute to learning.

Lishinski and colleagues [17] found a reciprocal relationship between self-efficacy and performance in programming, however this relationship was additionally found to be influenced by goal orientation and metacognitive strategies. This process also revealed gender differences, by females being influenced by the feedback earlier in the process compared to males. This suggests an increased risk of lowered self-efficacy among females due to early failures being internalized – which then influences further performance, enjoyment, and persistence within this field

1.3 Importance of Diversity Inclusion in Programming, Mathematics and HRI

Organizations within technology have been shown to be more innovative and increase their market growth when having diversity and inclusion in their workforce. Females have been shown to be an underrepresented group within STEM fields, and interventions focusing on gender diversity within STEM fields are advised to promote potential career choices to young students through role models [18]. Experience with, exposure to, and high academic performance within CS, in addition to social support and encouragement to pursue CS in future endeavors have all been found to be factors influencing persistence within CS. Additionally, females tend to rely on self-confidence and self-efficacy – and not so much on objective skills and abilities alone. Programming involvement and having the intent to continue learning CS while in high school have been found to be the most prominent predicting factors for persistence in CS among females [19].

1.4 Previous Findings

Gender has been identified as a moderating factor of accurate judgment of learning, where females are better at both self-assessment and performance assessment than males [20]. Although girls perform as competently as boys in various academic domains, they are inclined to report lower self-efficacy, especially in mathematics [21], and similar trends are reported in the field of programming. Although there is no significant difference between programming performances of students and gender [22, 23], there are differences in the perception of programming for girls and boys [24, 25]. Studies have shown that girls' attitudes towards programming are significantly lower than boys' [25-27].

Girls have been found to underperform within STEM if they were presented stereotypes of females performing worse than men on mathematics tasks, compared to when no such information was given [28]. However, it is suggested that such stereotype threat is of greatest influence on performance within mathematics when identification with mathematics (e.g., motivation) is high and the level of difficulty is neither too high nor low, but at the boundary of their abilities [28]. Having a female teacher has been shown to be associated with fewer gender differences on programming tasks, while boys were found to outperform girls when having male teachers [29].

Recent findings have shown that females perform no worse than males [2, 30]. Situational factors such as mentoring, female role-models and peer-support were identified [2] as contributing to retention and enhanced performance among female students at a cyber-defence academy. Accounting for gender difference in learning environments and introducing approaches that minimize risks associated with for example low self-efficacy and anxiety may directly support metacognitive development.

There have been found gender differences in attitudes towards robots, in that females reported higher social and physical attraction towards more human-like robots compared to males who reported better liking of the robot with the least human likeness [31].

Within mathematics, girls have been found to show lower self-efficacy compared to boys, and additionally boys reported a greater liking towards learning mathematics compared to girls, however with small cross-cultural effect size on the latter [32]. Girls and boys have been found to be equivalent in mathematic solving abilities, although they have been shown to use different strategies: boys tended to use covert strategies, such as retrieval, while girls tended to use overt strategies, such as counting on fingers [33].

Females exhibit lower mathematics and computer self-efficacy than males with significant gender differences emerge in late adolescence for mathematics self-efficacy

[34] as well as decline in girl's interest in learning computer-related skills [35]. Other studies report mixed gender results in computer self-efficacy [36], and no significant gender differences in mathematics [37], STEM [38] self-efficacy and CS performance [39]. Hence it can be concluded that findings have been inconsistent regarding gender differences in academic self-efficacy [34], and therefore, further investigation is required.

1.5 Aims of Study

This research aims to identify gender differences and psychosocial perceptions of experiences (difficulty, enjoyment and learning) in a CS education class where students participate in human-robot interaction, programming, and mathematics tasks.

2 Methods

2.1 Participants

The participants were Grade 6 students attending a primary school in a medium sized town in Norway (N=17; n_{female}=6).

2.2 Measurements

Independent Variable
Metacognitive assessment (JOP): Participants were asked for a metacognitive judgment concerning how they expected to perform working with the mathematics, human-robot interaction, and programming. All judgements were measured on a 5 point visual analogue scale. Before the task, participants were asked 'How well do you think you will be able to do on the task?' and after the task was completed, they were then asked 'How well do you think you did on the task?'. The judgment of performance accuracy was defined as ratio between self-assessed performance expectation (JoP_{pre}) and their actual perceived performance after task completion (JoP_{POST}) given by the formula:

$$JoP = \left(\frac{(JoPpost - JoPpre)}{JoPpost}\right)$$

Scores closer to 0 correspond to more accurate performance judgements, scores less than zero indicate overestimation performance, and scores greater than zero indicate underestimation of performance

Dependent Variables:
The dependent variables were defined as learning, fun, and difficulty in each category (human-robot interaction, mathematics, programming). Learning, fun, and difficulty perceptions were measured on single 5-point likert scales (not-very) for each of the

categories. A total score for fun was also computed by summing the individual fun scores (Cronbach's α=.762).

2.3 Procedure

The data was collected during a 3-day workshop which involved the following activities:

- Activity 1 - Introduction to humanoid robots - presentation and class discussion led by the researchers.
- Activity 2: The participants completed a structured online pre-test questionnaire on a secure platform. The information gathered was completely anonymous.
- Activity 3 – The class teachers divided the participants into gendered groups of four or five. The researchers conducted each group through an hour-long session. The robot was used to do basic programming and mathematics tasks during the lesson. The mathematics exercises were created in consultation with class teachers to ensure that they were appropriate in difficulty and curriculum-related.
- Activity 4 - After the tasks, the participants completed a secure online post-test structured questionnaire. The information gathered was completely anonymous.

2.4 Ethical Approval

The study conformed to the ethical guidelines for experimental studies set by the Norwegian Social Science Data Services (NSD). After the initial NSD online application was filled in, formal application was not required since only non-identifiable and non-health-related data were used in this research. Written informed consent was obtained from parents/guardians of the participating students. In addition, the students were informed about the aims of the project, their role in it, planned use of the data, and their right to withdraw. Participants were informed that they could withdraw from participation at any time and without any consequences throughout and after the session. However, it was made clear to them that the pre-test and post-test data was anonymous and therefore their survey data could not be withdrawn. The secure online provider used for the pre and post-test surveys is authorized by the author´s research institutions.

2.5 Data Reduction and Analysis

JASP version .14.1 was used for statistical analysis. Due to the number of participants, non-parametric mean comparisons were used to test the hypothesis for gender differences. Alpha levels were set to .05.

3 Results

Descriptives for each gender are given in Table 1. To test for gender differences, non-parametric means comparison (Mann-Whitney *U*) analysis was done. While there were no significant differences between genders, there were differences with small to medium effect sizes (*RBC* = .278 - .389; see Table 1).

Girls were more accurate in their performance judgements in human-robot interactions (*RBC* = .278), but even though they were less accurate in their mathematics (*RBC* = .028) and programming (*RBC* = .000) judgements compared to boys, these differences were negligible.

Girls reported equal or more fun on all three tasks than the males (HRI: *RBC* = .000; mathematics: *RBC* = .389; Programming: *RBC* = .333).

Girls did have divergent reports on their perceived difficulty. While girls reported less difficulty in the interactions with the robot (*RBC* = .500) they also reported more difficulty than boys in the mathematics tasks (*RBC* = .389). Due to a technical error during data collection difficulty scores for programming were not recorded.

Overall, females reported that they learned less (*RBC* = .167) but had more fun (*RBC* = .278) than the males. Both males and females rated the CS course equally as difficult (*RBC* = .000).

Table 1: Gender differences (*N* = 12)

	Mean		***U***	**p**	**ES**
	Males	**Females**			
JOP HRI Accuracy	.17±.20	.07±.19	23.00	.451	.278
JOP Math Accuracy	.06±.23	.08±.20	17.50	1	.028
JOP Programmng Accuracy	.08±.39	.11±.28	18.00	1	.000
Fun with HRI	4.83±.41	4.83±.41	18.00	1.00	.000
Fun with Math	3.83±1.42	4.33±.51	16.00	.247	.389
Fun with Programming	4.33±.52	4.67±.52	12.00	.311	.333
Difficulty with HRI	2.50±.55	1.83±.75	27.00	.137	.500
Difficulty with Math	2.17±.75	2.67±.52	11.00	.247	.389
Total Learning	1.67±.1.03	1.33±.82	21.00	.595	.167
Total Fun	9.17±.75	9.50±.84	13.00	.432	.278
Total Difficulty	4.67±1.03	4.50±.1.05	20.00	.801	.000

ES: effect size given by Rank Biserial Correlation; JOP: Judgement of Performance; HRI Human-Robot Interaction

4 Discussion

This study set out to investigate gender differences in performance judgements and in psychosocial experiences (difficulty, enjoyment and learning) in a classroom course focused on human-robot interaction, mathematics, and programming.

Previous research showed that gender was a predictive factor in perceived judgments of performance where females are better at self-assessing their skills [20]. While there were no significant gender differences found in our study, some tendencies (small to medium effect sizes; RBC=.278-.389; see table 1) did emerge that support previous findings. While there were no significant gender effects, there were differences with small effect sizes. Girls did have divergent reports on their perceived difficulty as reported in previous research. While girls reported less difficulty with interactions with the robots (RBC=.500), they did report the mathematics as being more difficult (RBC=.389) to work with. Girls reported better accuracy in their robot interaction perceptions (RBC=.278), more fun with programming (RBC=.333), and less learning (RBC=.167). In the mathematics condition, girls also reported more difficulty (RBC=.389) but also reported that mathematics was more fun (.389). This gives support to the Schripsema et al. [20] findings that females may be better at self-assessment, especially at school ages where girls are generally better at self-regulated learning [13], and to findings that females perform as good as males in programming when situational factors are accounted for [19].

The associations found in this study, that females reported better outcomes than males, supports more recent findings that females who receive programming experience increased their interest in technology and programming [30]. This may lead to more persistence in pursuing and continuing STEM education in females [2, 19, 29]. This may be moderated by situational factors such as same sex peer support and instructor gender [2, 29].

One aspect that might have influenced the results of this study was that the course the students completed was delivered by two female teachers, one with expertise in CS and one with expertise in pedagogy development. The girl's performance on the different tasks can be moderated by the teachers. Previous research has shown that same gender role models can increase self-efficacy which also influences performance [2, 4, 29]. This may have contributed to the more positive results for females in enjoying human robot interaction while experiencing less difficulties in the interactions. While both teachers have competencies in education ad CS, this may also explain the results for the mathematics tasks. The girls reported more difficulty with the mathematics, similar to previous findings [21] but that they enjoyed the mathematics task more than the boys may be due to access to the same sex role model [29].

The students participating in the study are preadolescent and this may also explain the non-significant findings. Previous studies show mixed results where late adolescent males report higher self-efficacy in mathematics but primary and middle school children do not show any differences [35, 37, 38].

While this study did not find any significant differences, it does highlight the importance of other psychological factors that may influence female participation in CS and STEM education. Females who are exposed to CS and STEM subjects early in their educational development, and who have access to same gender role models, are more likely to persist in the field and develop careers within CS [18, 19].

4.1 Limitations of Study

This study only included twelve participants, and this may explain the non-significant findings. Also, the measurements used in this study are self-reports. Alongside the age of the participants, the self-evaluation of their performance and experiences may be subject to wide variance of understanding. The course was delivered by female teachers, and as with the benefits of same gender role-models, the boys in this study may have been negatively influenced due to the lack of a male role-model. The gender of the teacher has been shown to influence student performance [24, 25].

5 Conclusion

The study showed that preadolescent boys and girls report similar experiences with a CS course that included human-robot interaction, mathematics, and programming. This study included students' perceptions of their performance, an aspect future studies should incorporate into their designs and that situational factors, such as teacher gender, might impact student experiences. CS research and instruction should include both male and female teachers as this could be an influencing factor on student performance and future career choices.

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References

1. Murciano-Goroff, R., *Missing women in tech: The labor market for highly skilled software engineers.* Work in progress. http://stanford. edu/~ ravivmg/papers/JMP. pdf, 2018.
2. Lugo, R.G., et al. *Cognitive profiles and education of female cyber defence operators*. in *International Conference on Human-Computer Interaction*. 2019. Springer.
3. Lehman, K.J., L.J. Sax, and H.B. Zimmerman, *Women planning to major in computer science: Who are they and what makes them unique?* Computer Science Education, 2016. **26**(4): p. 277-298.
4. Karlin, M., *Strategies for Recruiting and Retaining Female Students in Secondary Computer Science*, in *School of Education*. 2019, Indiana University. p. 223.

5. Lin, P., K. Abney, and G.A. Bekey, *Robot ethics: the ethical and social implications of robotics*. 2012: Intelligent Robotics and Autonomous Agents series.
6. Newton, D.P. and L.D. Newton. *Humanoid robots as teachers and a proposed code of practice*. in *Frontiers in Education*. 2019. Frontiers.
7. Pandey, A.K. and R. Gelin, *Humanoid robots in education: a short review.* Humanoid robotics: a reference, 2017: p. 1-16.
8. Alcorn, A.M., et al., *Educators' views on using humanoid robots with autistic learners in special education settings in England.* Frontiers in Robotics and AI, 2019. **6**: p. 107.
9. Ahumada-Newhart, V. and J.S. Eccles, *A Theoretical and Qualitative Approach to Evaluating Children's Robot-Mediated Levels of Presence.* Technology, Mind, and Behavior, 2020. **1**(1).
10. Crompton, H., K. Gregory, and D. Burke, *Humanoid robots supporting children's learning in an early childhood setting.* British Journal of Educational Technology, 2018. **49**(5): p. 911-927.
11. Jones, A. and G. Castellano, *Adaptive robotic tutors that support self-regulated learning: A longer-term investigation with primary school children.* International Journal of Social Robotics, 2018. **10**(3): p. 357-370.
12. Efklides, A., *Metacognition: Defining its facets and levels of functioning in relation to self-regulation and co-regulation.* European Psychologist, 2008. **13**(4): p. 277-287.
13. Zimmerman, B.J. and D.H. Schunk, *Handbook of self-regulation of learning and performance*. 2011: Routledge/Taylor & Francis Group.
14. André, V., et al., *Ethorobotics applied to human behaviour: can animated objects influence children's behaviour in cognitive tasks?* Animal Behaviour, 2014. **96**: p. 69-77.
15. Ahmad, M.I., et al., *Robot's adaptive emotional feedback sustains children's social engagement and promotes their vocabulary learning: a long-term child–robot interaction study.* Adaptive Behavior, 2019. **27**(4): p. 243-266.
16. Bavelier, D., C.S. Green, and M.W. Dye, *Children, wired: For better and for worse.* Neuron, 2010. **67**(5): p. 692-701.
17. Lishinski, A., et al. *Learning to program: Gender differences and interactive effects of students' motivation, goals, and self-efficacy on performance*. in *Proceedings of the 2016 ACM Conference on International Computing Education Research*. 2016.
18. Peixoto, A., et al. *Diversity and inclusion in engineering education: Looking through the gender question*. in *2018 IEEE Global Engineering Education Conference (EDUCON)*. 2018. IEEE.
19. Weston, T.J., W.M. Dubow, and A. Kaminsky, *Predicting women's persistence in computer sciencecomputer science-and technology-related majors from high school to college.* ACM Transactions on Computing Education (TOCE), 2019. **20**(1): p. 1-16.

20. Schripsema, N.R., et al., *Impact of vocational interests, previous academic experience, gender and age on situational judgement test performance.* Advances in Health Sciences Education, 2017. **22**(2): p. 521-532.
21. Schunk, D.H., J.R. Meece, and P.R. Pintrich, *Motivation in education: Theory, research, and applications*. 2012: Pearson Higher Ed.
22. Lau, W.W. and A.H. Yuen, *Modelling programming performance: Beyond the influence of learner characteristics.* Computers & Education, 2011. **57**(1): p. 1202-1213.
23. Su, A.Y., et al., *Investigating the role of computer-supported annotation in problem-solving-based teaching: An empirical study of a S cratch programming pedagogy.* British Journal of Educational Technology, 2014. **45**(4): p. 647-665.
24. Gunbatar, M.S. and H. Karalar, *Gender Differences in Middle School Students' Attitudes and Self-Efficacy Perceptions towards mBlock Programming.* European Journal of Educational Research, 2018. **7**(4): p. 925-933.
25. Rubio, M.A., et al., *Closing the gender gap in an introductory programming course.* Computers & Education, 2015. **82**: p. 409-420.
26. Baser, M., *Attitude, gender and achievement in computer programming.* Middle-East Journal of Scientific Research, 2013. **14**(2): p. 248-255.
27. Korkmaz, Ö. and H. Altun, *Engineering and ceit student's attitude towards learning computer programming.* The Journal of Academic Social Science Studies International Journal of Social Science, 2013. **6**(2): p. 1169-1185.
28. Spencer, S.J., C.M. Steele, and D.M. Quinn, *Stereotype threat and women's math performance.* Journal of experimental social psychology, 1999. **35**(1): p. 4-28.
29. Sullivan, A. and M. Bers, *The impact of teacher gender on girls' performance on programming tasks in early elementary school.* Journal of Information Technology Education: Innovations in Practice, 2018. **17**(1): p. 153-162.
30. Master, A., et al., *Programming experience promotes higher STEM motivation among first-grade girls.* Journal of experimental child psychology, 2017. **160**: p. 92-106.
31. Tung, F.-W. *Influence of gender and age on the attitudes of children towards humanoid robots*. in *International Conference on Human-Computer Interaction*. 2011. Springer.
32. Reilly, D., D.L. Neumann, and G. Andrews, *Investigating gender differences in mathematics and science: Results from the 2011 Trends in Mathematics and Science Survey.* Research in Science Education, 2019. **49**(1): p. 25-50.
33. Carr, M. and D.L. Jessup, *Gender differences in first-grade mathematics strategy use: Social and metacognitive influences.* Journal of Educational psychology, 1997. **89**(2): p. 318.
34. Huang, C., *Gender differences in academic self-efficacy: A meta-analysis.* European journal of psychology of education, 2013. **28**(1): p. 1-35.

35. Blackhurst, A.E. and R.W. Auger, *Precursors to the gender gap in college enrollment: Children's aspirations and expectations for their futures.* Professional School Counseling, 2008. **11**(3): p. 2156759X0801100301.
36. Peng, H., C.C. Tsai, and Y.T. Wu, *University students' self-efficacy and their attitudes toward the Internet: the role of students' perceptions of the Internet.* Educational studies, 2006. **32**(1): p. 73-86.
37. Friedel, J.M., et al., *Achievement goals, efficacy beliefs and coping strategies in mathematics: The roles of perceived parent and teacher goal emphases.* Contemporary Educational Psychology, 2007. **32**(3): p. 434-458.
38. Brown, P.L., et al., *An Examination of Middle School Students' STEM Self-Efficacy, Interests and Perceptions.* Journal of STEM Education: Innovations and Research, 2016. **17**(3).
39. Qian, Y. and J.D. Lehman, *Correlates of Success in Introductory Programming: A Study with Middle School Students.* Journal of Education and Learning, 2016. **5**(2): p. 73-83.