International Journal of Gender, Science and Technology
http://genderandset.open.ac.uk

Making Game-Making Work for Girls

Jennifer Jenson[1], Karen Skardzius[2], Karen R. Black[3], Suzanne de Castell[4]
[1]University of British Colombia, [2]Vancouver Island University, [3]York University, [4]Simon Fraser University, Canada

ABSTRACT
As digital game-making becomes an increasingly popular way to teach computational and design-based thinking and learning, educators must contend with gender-based differences in how students engage with game making. In this study, girls learned more from game making than boys, but that took some doing. Pedagogical innovation cannot be gender-blind, especially when it comes developing students' essential digital and computational skills. Reported here is a study of grade six students who participated in game making workshops in same-gender groups. Using a mixed-method approach, we examined whether children's pre-existing biases and previous experiences related to computer science and programming were associated with change in computational knowledge following their participation in an intensive 1-week game design program. We found that all students performed better from pre- to post, that girls learned relatively more from the program than boys, enabling them to both catch up to and exceed boys in pre/post-program assessment. We also found that prior programming knowledge had a significant effect on learning outcomes. Given boys' historically more frequent and less restricted access to digital games and technology, this prior knowledge effect situates girls at significant disadvantage, one that educators need to acknowledge and address when using game-making as a teaching tool.

KEYWORDS
gender, digital game making, STEM, coding, Game Maker

Making Game-Making Work for Girls

INTRODUCTION

Given recent attention on STEM related skills and "coding for all", researchers have been examining the potential of making digital games as a pathway to computational and designed-based thinking and learning. With the recent proliferation of accessible and affordable coding tools (e.g. Scratch, Game Maker, Alice), many educators are turning to game making as a means of teaching a variety of coding and other STEM-related skills. As learning through making games becomes more prevalent in formal and informal education programs, it is increasingly important to understand gender-based differences in how students engage with and benefit from game making.

This paper reports on a study of middle-school students (grade six) who participated in game making workshops in same-gender groups[1]. Our findings suggest that prior programming knowledge has a significant effect on the learning outcomes regardless of gender. Given that in general, boys have easier access to and more experience with digital games, programming, and technology more broadly, this leaves many girls starting at a disadvantage. We argue that educators need to consider and actively intervene to correct for that disadvantage when using game making in their pedagogy.

RELATED LITERATURE

Gender Disparities in STEM

Research continues to demonstrate gender-based differences related to computer programming confidence and STEM-related educational and career choices (Wang, et al. 2013). We know that women are underrepresented in computer science and engineering programs and the tech-industry in general, and that has been the case for several decades (Ashcraft, McLain & Eger, 2016; Denner & Campe, 2018; Hango, 2013; Hill, Corbet & Rose, 2010). How to remediate that remains a significant research, educational, social, and political issue, one that is not easily untangled from technicist cultural norms that view and treat men as more technically skilled than women.

One long understood contributing factor to women's underrepresentation in undergraduate computer science and engineering programs has been that many girls do not choose to take or are unaware of programming and other courses in high school (Anderson, et al. 2008). This is often because they are not counselled by teachers or other guidance counsellors to take those courses or their friends are not taking them (Howe, Berenson & Vouk, 2007). A common strategy to address this problem has been to target girls and women with female-focused coding/recruitment programs and camps to stimulate interest in STEM careers. To better understand the gender gap in STEM fields, Cardador, Damian & Wiegand (2020) developed a "surplus model" of vocational interests. They found that when women are interested in STEM fields, but also have interest(s) in other viable career paths – especially artistic and/or enterprising fields - they are less likely to pursue a career in STEM. Cardador et al. (2020) suggest that when targeting girls with programs designed to increase interest in STEM careers, the program should not only focus on instrumental STEM skills, but also STEM careers that bring together their varying interests (e.g. arts & STEM). Importantly, they explain that part of women's decisions not to pursue STEM careers even when they are interested in the subject is because women are likely to experience bias and discrimination in those jobs, and so choosing another career path that would be equally interesting is more appealing.

It is well documented that classrooms and workplaces in STEM fields are often unwelcoming and even hostile towards women. Research shows that many women enrolled in STEM degrees experience gender bias from their peers and sexual harassment from instructors, leading to decreased STEM motivation and career aspirations (Casad, Petzel & Ingalls, 2019; Leaper & Starr, 2019; Madara & Cherotich, 2016; Male et al., 2018). For women who do enter STEM careers, they are often met with gender-based challenges related to pay inequity, work/life balance, workplace culture (i.e. having to become "one of the guys" to fit in), harassment and/or gender bias, and a lack of access to senior positions (Friedmann & Efrat-Treister, 2023; Professionals Australia, 2015; Swafford & Anderson, 2020). Representation and mentorship are important factors in attracting and retaining underrepresented groups to STEM fields. González-Pérez, de Cabo & Sáinz (2020) found that the most effective way to encourage girls to pursue STEM fields is to expose them to female role models who are successful in that professional field.

Seeing and hearing from women who are succeeding in STEM creates opportunities for girls to imagine themselves as being successful too. This is especially the case when girls see how skills not often associated with STEM fields (e.g. teamwork, communication, social skills) are actually in high demand across STEM careers. Mentorship is often suggested as a useful tool for closing the gender gap in STEM, yet research consistently demonstrates that although women may have initial access to mentorship, they still experience significant barriers that inhibit long-term mentorship (Saffie-Robertson, 2020). Kricorian et al., (2020) found that students are encouraged to pursue and persist in STEM education when they have access to a mentor of their same gender and ethnicity. This is a difficult challenge given the dearth of women, and especially women of colour, in STEM fields. O'Connor et al. (2020) argue that men enrolled in advanced STEM degrees have what they call an "invisible advantage" when it comes to mentorship (p. 765). They suggest that while both men and women receive mentorship while pursuing their PhDs, men are more likely to get career-related advice and assistance, while women were more likely to get emotional support and reassurance. Moreover, men are also more likely to receive sponsorship, which O'Connor et al. (2020) explain as the leveraging of power, reputation, and influence to advance the career of a mentee.

They argue that this is one of the mechanisms of patriarchal reproduction in STEM, ensuring that men retain places of power while women continue to be pushed out. Although there is plenty of research being done to understand how and why women and girls are underrepresented in STEM (c.f. Aladé, et al. 2020; Bennett, et al. 2021), there is much less intersectional research to understand the persistent employment gaps around race, class, ability, sexuality, and other underrepresented groups. Shadonna Davis (2020) examined educational pathways to STEM careers for a group of Black high school girls. She found that although the girls were keenly aware of how race and class influence their general educational experience (e.g. under-resourced schools, underqualified teachers/teachers who have low expectations of them, disproportionately high suspension rates), they knew little about racial and gender disparities related to STEM educational pathways. Once provided information about how few Black girls in the US take AP math/computer science courses, the girls began reciting negative stereotypes of Black girls as explanations, blaming the girls and not the education system. In their study of Asian-American female doctoral candidates in STEM, Castro & Collins (2021) found that there are many programs (training, workshops, talks) that highlight gender-based experiences of working in STEM, but it is rare to find similar programs that emphasize racial identities. The point is, much more work needs to be done to work intersectionally in our methods and our analysis, and we acknowledge that this is largely aspirational in this text, though decidedly purposeful.

When educators use digital games in their lessons, being aware of the differences and disparities in students' experience levels, and how they have engaged with technology is a good starting point. Moving past that starting point should include gaining an understanding of how different groups of students have been underrepresented and/or marginalized in STEM subjects, then using evidence-based strategies to achieve more equitable learning outcomes for all students.

Making Games for Learning

Digital gameplay has been used as a pedagogical tool in classrooms for some time, but game making for learning has only recently been taken up by educators. One explanation for this discrepancy could be that historically, the tools for game design were neither widely available, nor user-friendly for those with limited to no coding experience. That said, over the past decade, a plethora of tools have been created and made accessible to even the most novice of coders. Drag-and-drop, graphically oriented programming environments targeted specifically for children such as Scratch, Kodu and Alice, and others like Game Maker, Construct 2, Neverwinter Nights and Unity (which are not all targeted for classrooms/students) have been held up as environments that can support the acquisition of STEM-related competencies and skills, as well as those directly related to game design (Koh, et al. 2013; Navarrete, 2013; Robertson, 2012). Game making tools have evolved to a point that they now support making games almost as easily as playing them.

There are also gender specific initiatives tied to supporting girls making games as pathways to STEM-based competencies and interests (de Carvalho, et al., 2020). Computer game design has been explored as an interdisciplinary way to support girls' computer programming competencies. Denner's (2011, 2012, 2019, 2022) work and with colleagues over the last two decades is especially important to connect with this study as it has demonstrated that computer game programming can increase girls' computer skills and overall computer programming confidence. Jenson & Droumeva (2016; 2017) also found that both boys and girls improved their overall understanding of computer programming competencies after participating in a game design program. Denner, Wenner & Ortiz (2012) specifically examined the relationship between computer game creation by middle school girls and the acquisition of computer science concepts. They found that "computer game programming is a promising approach to engage underrepresented students [in their case girls] in the concepts and capabilities that will prepare them for computer science courses and careers" (p. 245). That said, they also found that novices needed more support than they were given in their study to understand and implement more complex coding tasks.

Studies like Aurava and Meriläinen (2022) show compelling links between game construction and increased confidence in computational literacy for high school students. Another study found that students who used Storytelling Alice (a programming environment) during class or in an after-school club improved their basic programming abilities as well as learning more complex constructs such as "abstractions" and "concurrent execution" (Werner, Denner, & Campe, 2014). A subsequent study looked at students in pairs, and their interactions when sharing a game design project (Denner, Green, & Campe, 2021). Many others have documented the acquisition of computational concepts through game design projects (Aurava & Meriläinen, 2022; Denner et al., 2012, 2021; Howland & Good, 2015; Kafai & Peppler, 2012; Mozelius & Humble, 2023). However, as Kafai & Burke (2015) point out, there are far fewer studies that examine learning through game making than there are learning through game playing. They argue that "participation in serious games is not solely a matter of making better games for learning but allowing students themselves to make the games they would like to see and play" (p. 327).

A Case for Same-Gender Groups in Game-Making Workshops

Given the overwhelming evidence of gender disparities found in STEM subjects and educational settings, it is worth discussing the case for gender-specific or same-gender groups while teaching through making games. In most cases, boys come to game-making having had more access to and experience with video games, coding, and technology in general (Jenson & de Castell, 2011). Boys also benefit from the cultural assumption that they not only belong in game-making spaces, but that they will thrive. Video game culture is a highly contested space where the games are mostly made by men/for men, and women are routinely objectified, harassed, erased, and generally made to feel unwelcome (Blodgett, 2020; Fox & Tang, 2017). From prior research using games in the classroom, we know that boys can quickly dominate the space, consuming the instructor's attention, asking/answering all the questions, and taking over physical control of the electronic devices. We also know that girls often dismiss their own gameplay abilities or engage in self-deprecating talk, while boys are quick to celebrate their own achievements (Jenson and de Castell, 2011). Same-gender groupings are one strategy to mitigate these disparities.

Although there is an abundance of research on the topic of "same-sex education", a great deal of it is embedded in an ideological and politically motivated debate, particularly in the US context. We found this debate to be outside the intent for this paper, so we focused our efforts on a review of same-gender education that was limited to STEM classes or STEM-related short-term camps/workshops. Most studies reported inconclusive, or mixed results after implementing same-gender settings for specific subjects in middle-school or high-school aged students (Abraham & Barker, 2020; Feniger, 2011; Hughes, Nzekwe & Molyneaux, 2013; Law & Sikora, 2020; Park, Behrman & Choi, 2018) and the majority agree that further research is needed to make any definitive claims. While studying strategies for mitigating stereotype threat, Bowe et al. (2017) compared single-sex and co-ed math classes and found that African American 6th grade girls demonstrated improved math achievement in single-sex classrooms. Hoffman, Badgett & Parker (2008) compared the achievement outcomes of students in single-sex and co-ed Algebra and English high-school classes over a two-year period. They report inconsistent results, where the single-sex groups showed algebra achievement gains in the first year but not the second year, and there was no achievement difference in the English classes.

The co-ed groups achieved higher results on standardized testing overall. What is arguably most interesting about this study is the findings around classroom culture and participant perspectives of the experience. Teachers generally found the single-sex groups more conducive to learning, finding especially that girls were more willing to engage in academic risk-taking and participate more readily in class.

Specifically, they found that

> Girls in [single-sex instruction] worked collaboratively, actively engaged in classroom discussions and activities, encouraged and congratulated one another, voiced excitement about content, and asked and answered questions more often. Girls in [co-ed] classes behaved differently. They interacted with teachers less than did boys and were often ignored when they tried. (Hoffman, Badgett & Parker, 2008, p. 26)

Although teachers had a generally positive outlook about single-sex instruction, students were generally disdainful of them and preferred co-ed classes.

STUDY DESIGN

This study took a mixed methods approach in its design. A mixed methods approach allowed us to, as Creswell (2013) states, collect "diverse types of data" that allow for a "more complete understanding of a research problem than either quantitative or qualitative data alone" (p. 19). The working hypothesis for the study was that girls (and boys) in the study would increase their computational understandings through making games. We collected data over six consecutive days while four groups of grade 6 students (N = 59, median age = 11, female = 32, male = 27) learned to use the game design software Game Maker to construct games with a team of researchers and facilitators. The school was located in what is considered an "inner city" neighbourhood in the Greater Toronto Area in the Province of Ontario, Canada. Study participants were a multicultural group, primarily from the Middle East and South Asia, with a few Filipino, Chinese, White, and Black students. Several of the students (5) were E.L.L. (English Language Learners), who were not normally integrated into this kind of activity as the

school's ELL program was designed to pull students out for their English-language arts lessons.
Participants engaged with Game Maker (robust game making software that has been used to design commercial games) for a total of 15 hours of instructional support time and with students working in same-gender pairs. Quantitative data included pre- and post- assessments and a media literacy and programming attitudes questionnaire. All participants completed identical assessments before, and immediately after the study. The assessments included an evaluation of knowledge of computer programming concepts (i.e. variables, operations, functions and general programming knowledge). Qualitative data included observations and fieldnotes of each session and an analysis of the digital games produced, which were ranked in terms of complexity and playability.

In terms of the session, Game Maker instruction followed the same curriculum for all participants and included both direct instruction and facilitator supported, self-guided activities for participants. This near-peer support was scaffolded to encourage retention and application of new material and concepts for participants. At any given time at least four facilitators, one researcher, and one instructional leader were present to support students and document and observe the sessions.

Study Routine

Each morning, the game design facilitators arrived 20-30 minutes before the first group of students arrived in order to set-up the equipment in a "portable" (designed to be temporary, but in the case of many schools in Canada, they end up being permanent fixtures to accommodate more students and teachers) classroom as the grade 6 classes were all held in a block of three classrooms that were in small trailers outside the main school structure. For the duration of this study, there was a portable designated for the project, so the students left their classrooms/portables and came to the research team. Each day there were two groups of participants, one in the morning and one in the afternoon. The 90-minute sessions involved one hour where the primary facilitator, a young woman who designs games, would walk the students through the designated curriculum.

After direct instruction, the participants used the skills and concepts they learned in the tutorial to develop their own games. They were particularly encouraged to create a game within the context of five specific types of games (ball and paddle (Pong-like), maze, 2D adventure, platformer, racing) because the facilitators had the most experience with those types. On day four and day six, after the tutorial, the students completed mini-coding challenges to test the knowledge and skills they had acquired. On these days, students only had time to work on their games if they had finished their challenge before the end of the session. In the first challenge, students were asked to create a Pong game; in the second challenge they were asked to create a Ball Collect game. Students worked in same-gender pairs for all parts of the session (i.e. tutorial, game development, and Challenges). The students worked with the research team for six days at the school and one day during a field trip to the local university. In the next section, we report on the quantitative data from the study, including its analysis and results. In the discussion portion of the paper, where relevant, we also add details from the observations and fieldnotes.

ANALYSIS

All statistical analyses were completed with IBM SPSS Version 24.0. A series of one-way repeated measures ANOVAs were used to compare scores across groups at pre- and post-test for Programming Knowledge, Programming Confidence, and Attitudes Toward Programming; paired-sample t-tests were run to examine significant contrasts. Next, independent sample t-tests were conducted to examine individual differences between girls and boys related to home ownership of computational devices, as well as frequency and type of device used for gameplay. Finally, Spearman's correlations were used to explore whether device ownership, type and frequency of use were related to significant differences in score changes across genders.

Two composite variables were created by summing items from the media literacy/attitudes questionnaire: Programming Confidence and Attitudes Toward Programming. In addition, children reported on the number of computer and game-based devices in their homes, as well as on their frequency of computer gameplay (1 - never, 2 - 1-2 times/month, 3 - 1-4 hours/week, 4 - 5 - 9 hours/week, 5 - > 10 hours/week). Programming Confidence included 14 items related to comfort levels in daily use of programming and computer skills (e.g. "I can learn to understand computer programming concepts") and showed good internal consistency across items ($\alpha = 0.78$). Attitudes Toward Programming summed 3 items examining participant's attitudes based on perceived gender roles (e.g. "Computer programming is an appropriate subject for both boys and girls") and showed high internal consistency ($\alpha = 0.86$). Both variables were rated on a 6-point Likert scale (0 - strongly disagree to 5 - strongly agree), with higher scores indicating both more confidence, and less biased views about technological skill (e.g. males are better at computer programming than females).

Following completion of the program, each participant's video game was rated by two graduate assistants for polish, completeness and inclusion of basic or advanced programming concepts via two additional variables that were combined together: Game Design Complexity (score range: 4 – 58) and Playability (score range: 2 – 9). Game Design Complexity was defined as the sum of a set of 9 items which included: multiplayer capability, objects, levels, operations, variable settings, conditionals, functions, advanced coding and custom variables (Table 1). Playability was defined as the sum of a set of four items: polish, completeness, inclusion of a win condition and game or level re-start capability (Table 2). Higher scores indicated higher overall ratings of complexity and playability of the games created by participants.

Table 1: Game design complexity items, rating criteria and points awarded

Item	Points	Criteria
1. Multiplayer capability	1	If included
2. Number of objects	1+	Per object
3. Number of levels	1+	Per level
4. Number of operations	1+	Per operation
5. Number of variable settings	1+	Per variable setting
6. Number of conditionals	1+	Per conditional
7. Number of functions	1+	Per function
8. Advanced coding option	1	If included
9. Custom variables	1	If included

Table 2: Playability items, rating criteria and points awarded

Item	Points (3 possible)	Criteria
1. Usability	3 3 2 1	Is playable without Looks average Meets basics only/ is glitchy
2. Win condition	1	included/not
3. Game or level restart	1	included/not
4. Completeness	4 possible 4 3 2 1	Includes a beginning, middle and end Plays well, lacks features Not playable (e.g. no game progression, buggy, ill structured, non-interactive).

RESULTS

Pairwise comparisons from the repeated measure ANOVAs showed that overall, significant improvements in scores occurred from pre to post-test for Programming Knowledge (Wilks' Lambda = .30, $F(1,57) = 132.811$, $p < .0001$, $\eta_p^2 = .70$), Programming Confidence (Wilks' Lambda = .87, $F(1,57) = 8.46$, $p = 0.005$, $\eta_p^2 = .13$) and Attitudes Toward Programming (Wilks' Lambda = .87, $F(1,57) = 8.59$, $p = 0.005$, $\eta_p^2 = .13$). Further examination of contrasts via t-tests indicated that girls and boys showed large improvements in Programming Knowledge (girls: mean change = 4.55, $p < 0.001$, $d = 2.21$; boys: mean change = 3.65, $p < 0.001$, $d = 1.71$), with girls demonstrating an approximately 25% larger effect size than boys. Increased Programming Confidence was also observed for girls (mean change = 2.56, $p = 0.03$, $d = 0.36$), but no significant change in Attitudes Towards Programming (mean change = 0.47, $p = 0.14$). Boys showed a moderate effect for improvement in Attitudes (mean change = 1.11 $p = 0.02$, $d = 0.47$), and

Programming Confidence trended towards a significant increase with a small effect size (mean change = 1.56, p = 0.06, d = 0.17).

Independent sample t-tests (Table 3) and Spearman's correlations were performed next to further examine relationships between computational variables. For girls, initial Attitudes Towards Programming (at pre-test) showed consistent relationships with programming knowledge at each time-point (pre: $r_s = 0.46$, $p = 0.008$; post: $r_s = 0.45$, $p = 0.01$), and a similar relationship with programming confidence, with the latter demonstrating an increase in strength at post-test (pre: $r_s = 0.35$, $p = 0.05$; post: $r_s = 0.48$, $p=.005$). Girl's post-test attitudes maintained a moderate strength correlation with programming confidence at post-test ($r_s = 0.51$, $p=.003$). Pretest Attitudes were also positively related to Game Design Complexity ($r_s = 0.36$, $p = 0.05$) and reported frequency of gameplay with handheld console games ($r_s = 0.41$, $p = 0.04$). The total number of computer/game-based devices girls reported using at home also emerged as positively related to Game Design Complexity ($r_s = 0.45$, $p = 0.01$).

For boys, Game Design Playability was negatively related to reported frequency of handheld console gameplay ($r_s = -0.50$, $p = 0.009$) and tablet gameplay ($r_s = -0.52$, $p = 0.006$). Programming knowledge at post-test only was positively related to frequency of computer-based gameplay ($r_s = -0.46$, $p = 0.02$).

Table 3: Mean differences between girls and boys across variables

	Group								
	Girls (n = 32)		Boys (n = 27)		95% CI		t(df)	p	d
Variables	Mean	SD	Mean	SD					
Game Devices									
Total Number	3.31	1.40	4.30	1.96	0.11	1.86	2.24(57)	0.03	0.58
Frequency played – computer	2.30	1.26	2.59	1.97	-0.60	1.19	0.66(45.53)[a]	0.51	
Frequency played – console	1.94	1.39	3.63	1.64	0.90	2.49	4.25(56)	<0.001	1.11
Frequency played – MMO	1.74	1.38	3.22	1.95	0.57	2.39	3.29(46.28)[a]	0.002	0.87
Frequency played – handheld	2.82	1.44	2.78	1.58	-0.86	0.77	-0.11(53)	0.92	
Frequency played – tablet	3.39	1.38	2.96	1.58	-1.20	0.36	-1.09(56)	0.28	

Game design scores									
Playability	5.84	2.27	5.31	2.09	-1.71	0.62	-0.93(56)	0.36	
Complexity	30.97	13.20	35.31	14.24	-2.37	12.1	1.35(56)	0.18	
Programming Pre/Post Scores									
Knowledge – pre	5.03	2.06	5.07	2.13					
Knowledge – post	9.58	2.83	8.72	2.26					
Confidence - pre	53.34	7.07	54.30	9.07					
Confidence – post	55.91	7.48	55.85	8.32					
Attitudes – pre	13.16	2.50	13.44	2.38					
Attitudes - post	16.63	2.01	14.56	0.85					

Note: Total number includes: Desktop/laptop/MP# players/Smartphone/Cellphone/Console games; Console = Wii/Playstation/Xbox/Handheld/Other (iPad/Tablet); MMO = Multiplayer online
[a] = Equal variances not assumed

DISCUSSION

This study explored whether learning through game-making was associated with significant changes in computational knowledge and understanding at post-test. Results from the quantitative data provide support for our first hypothesis: girls showed a large change in their understanding of computational concepts, on average, demonstrating the ability to answer 4 to 5 more questions at post-test than on the first day of the study. This showed that a short intervention had quite a large impact on computational understanding for girls. Similarly, moderate effect sizes were observed for increases in Programming Confidence. This was reinforced in fieldnotes and observations, whereby a research assistant that had been part of a mixed-gender study the previous year observed:

> Last year, in mixed gender groups, the boys dominated the classroom space and made themselves more visible and noticeable in the group (i.e. they put their hands-up to participate in lessons and persistently asked for help more than the girls). This year, in single gender groups, both genders displayed these behaviours (i.e. put their hands-up,

> persisted in the face of challenges and asked for help). Overall, having the students in single gender groups seemed to have helped level-out the dramatic differences that were perceived between the boys and the girls last year (Research Assistant 2, Fieldnote).

Our second hypothesis was also supported in that boys demonstrated slightly smaller effect sizes for improvements in Programming Knowledge (answering 3 to 4 more questions at post-test), and a non-significant, but still notable effect for change in Programming Confidence. Contrary to predictions, attitudes towards programming did not measurably change for girls, despite findings of a small overall effect for the sample (as the effect was driven, in fact, by the attitude improvement reported by the boys). As our study did not explicitly target discussion of gender roles in STEM, this non-significant finding for girls is not necessarily surprising, and is in fact, in line with results noted by Denner (2007) who administered a study of the Girls Creating Games program to a group of 126 girls (mean age = 11.7 years). However, the change reported by the boys is interesting: as both groups of boys were taught by female instructors, the improvement in unbiased attitudes may be related to their impressions of the instructor's competency within an unfamiliar setting. Or it might simply be that the boys in the study benefited more than the girls did.

Findings from the fieldnotes tell a slightly different story in relation to programming knowledge and competence. Research Assistant 1 noted that: "students from both classes noticeably struggled with code" (i.e. it wasn't only the girls who struggled, which seemed to be a common assumption by the teachers). Examples of those struggles were in fieldnotes for both boys and girls. For example, the boys "L and M would get hung-up on typing or technical issues such as minimizing a window and not being able to find it again due to low computer literacy" (Research Assistant 1). Meanwhile, the girls "E and G had a compile error because they typed English as code for paddle movement" (Research Assistant 1). On the other hand, observations and fieldnotes also suggested that the girl groups moved from a kind of "quiet concentration" to excited talk about their successes with programming their games, movement around the room to support peers, and raising of hands to ask and answer questions. This occurred in both gender groups, but the research assistant who had been in the school the year before for a mixed-gender study noted time and again in their field notes that "not having the boys present in the girl groups meant they were raising their hands more and engaging with the facilitators more". They also noted that "the boys didn't dominate the technical question and answer periods" as that was now up to the girls to ask and answer "without hanging back and relying on the boys".

Notably, the effect size for overall change at post-test in Programming Knowledge was particularly large, representing 70% of the variance in the model. Without a control group for comparison, we cannot unequivocally separate the effect of time from children's participation in the study; however, considering that pre- and post-testing took place within a week, it seems unlikely that other learning contributed to the changes due to the passage of time. There is the possibility that some students may have continued to explore instructional videos related to Game Maker and increased their knowledge separate from the 15 hours of instruction.

LIMITATIONS

This study has several limitations: 1) it took place in a classroom over a short period of time, and therefore we had no prior experience with the participants, nor any prior knowledge of their routines or their behaviours; 2) there is a limited sample size; and 3) we did not, as we indicated at the start of this paper, look at the data intersectionally. That is in part because of the first limitation. At best, this paper is a snapshot of a period of time in the lives of these participants. That said, we think that this paper provides ongoing support for using video games making as a gateway for computational and STEM related understandings.

CONCLUSIONS

Overall, these findings highlight three critical aspects in relation to computational thinking. In our study, just one week of targeted instruction using game design software resulted in measurable changes in children's understanding of programming concepts, regardless of gender. However, gender differences - particularly in technology experience - can impact how children take up and apply their exposure to these concepts, and gender biases may play a significant role in children's confidence in their ability to excel in computation-based activities. Although we primarily saw improvement in students' understanding of those computational concepts, children may not equally take up computational learning opportunities, regardless of their intellectual abilities, when those opportunities are particularly stereotyped (e.g. that people who work in technology are antisocial, or that girls can't be tech-nerds). Educational research has demonstrated for decades that if students cannot imagine themselves as experts or are not confident in their abilities in a subject, they will not pursue education in that area, and this appears especially the case for girls and women and STEM fields (Hill, Corbett & Rose, 2010). This study highlights the need for pedagogical innovation that recognizes both the benefits, and the obstacles that game-making approaches pose for girls, and purposefully implements structures and approaches that better and more equitably support their engagement in game design, computer programming and computational thinking.

REFERENCES

Abraham, J., & Barker, K. (2020). Motivation and Engagement with Physics: A Comparative Study of Females in Single-Sex and Co-educational Classrooms. *Research in Science Education, 50*(6), 2227–2242.

Aladé, F., Lauricella, A., Kumar, Y., & Wartella, E. (2020). Who's modeling STEM for kids? A character analysis of children's STEM-focused television in the U.S. Journal of Children and Media, 1–20.

Anderson, N., Timms, C., Courtney, L., & Lankshear, C. (2008). Girls and information communication technology (ICT). Pp.181-201 in Rethinking Education with ICT. Yelland, N., Neal, G. A., and Dakich, E. (eds.). Sense Publishers: The Netherlands.

Ashcraft, C., McLain, B. & Eger, E. (2016). *Women in Tech: THE FACTS*. Retrieved from https://www.ncwit.org/sites/default/files/resources/ncwit_women-in-it_2016-full-report_final-web06012016.pdf.

Bennett, D., Bawa, S., & Ananthram, S. (2021). Gendered differences in perceived employability among higher education students in STEM and non-STEM disciplines. *Perspectives: Policy and Practice in Higher Education*, 1–7.

Blodgett, B. M. (2020). Media in the Post #GamerGate Era: Coverage of Reactionary Fan Anger and the Terrorism of the Privileged. *Television & New Media, 21*(2), 184–200.

Bowe, A. G., Desjardins, C. D., Covington Clarkson, L. M., & Lawrenz, F. (2017). Urban Elementary Single-Sex Math Classrooms: Mitigating Stereotype Threat for African American Girls. *Urban Education, 52*(3), 370–398.

Cardador, M. T., Damian, R. I., & Wiegand, J. P. (2021). Does More Mean Less?: Interest Surplus and the Gender Gap in STEM Careers. *Journal of Career Assessment, 29*(1), 76–97.

Casad, B. J., Petzel, Z. W., & Ingalls, E. A. (2019). A Model of Threatening Academic Environments Predicts Women STEM Majors' Self-Esteem and Engagement in STEM. *Sex Roles, 80*(7), 469–488.

Castro, A. R., & Collins, C. S. (2021). Asian American women in STEM in the lab with "White Men Named John." *Science Education*, *105*(1), 33–61.

Creswell, J. W. (2013). *Qualitative inquiry & research design: Choosing among five approaches* (3rd ed.). SAGE.

Davis, S. (2020). Socially Toxic Environments: A YPAR Project Exposes Issues Affecting Urban Black Girls' Educational Pathway to STEM Careers and Their Racial Identity Development. The Urban Review, 52(2), 215–237.

de Carvalho, C.V., Cerar, Š., Rugelj, J., Tsalapatas, H., & Heidmann, O. (2020). Addressing the Gender Gap in Computer Programming Through the Design and Development of Serious Games. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, *15*(3), 242-251. doi: 10.1109/RITA.2020.3008127.

Denner, J. (2007). The girls creating games program: An innovative approach to integrating technology into middle school. *Meridian: A middle school computer technologies journal*, *10*(1).

Denner, J. (2011). What predicts middle school girls' interest in computing? *International journal of gender in science, engineering, and technology*, *3* (1).

Denner, J., Werner, L., & Ortiz, E. (2012) Computer games created by middle school girls: can they be used to measure understanding of computer science concepts? *Computers & education, 58,* 1, 240–249.

Denner, J., Campe, S., & Werner, L. (2019). Does computer game design and programming benefit children? A meta-synthesis of research. *ACM Transactions on Computing Education, 19*(3), Article 19, doi: https://doi.org/10.1145/3277565

Denner, J., Green E., & Campe, S. (2021) Learning to program in middle school: How pair programming helps and hinders intrepid exploration, Journal of the Learning Sciences, 30:4-5, 611-645, DOI: 10.1080/10508406.2021.1939028

Denner, J. , & Campe, S. (2018). Equity and Inclusion in Computer Science Education. In S. Sentance, E. Barendsen, & C. Schulte (Ed.). *Computer Science Education: Perspectives on Teaching and Learning in School* (pp. 189–206). London: Bloomsbury Academic. doi: http://dx.doi.org/10.5040/9781350057142.ch-014

Feniger, Y. (2011). The Gender Gap in Advanced Math and Science Course Taking: Does Same-Sex Education Make A Difference? Sex Roles, 65(9), 670–679.

Fox, J., & Tang, W. Y. (2017). Women's experiences with general and sexual harassment in online video games: Rumination, organizational responsiveness, withdrawal, and coping strategies. *New Media & Society, 19*(8), 1290–1307.

Friedmann, E., & Efrat-Treister, D. (2023). Gender Bias in Stem Hiring: Implicit In-Group Gender Favoritism Among Men Managers. *Gender & Society*, *37*(1), 32-64. https://doi.org/10.1177/08912432221137910

González-Pérez, S., Mateos de Cabo, R., & Sáinz, M. (2020). Girls in STEM: Is It a Female Role-Model Thing? *Frontiers in Psychology*, 11.

Hango, D. (2013). Gender Differences in Science, Technology, Engineering, Mathematics and Computer Science (STEM) Programs at University. *Statistics Canada*. Retrieved from https://www150.statcan.gc.ca/n1/en/pub/75-006-x/2013001/article/11874-eng.pdf?st=oRAiLXeL.

Hill, C., Corbett, C., & Rose, A. (2010). Why So Few? Women in Science, Technology, Engineering, and Mathematics. In *American Association of University Women.* American Association of University Women. Retrieved from https://eric.ed.gov/?id=ED509653.

Hoffman, B. H., Badgett, B. A., & Parker, R. P. (2008). The Effect of Single-Sex Instruction in a Large, Urban, At-Risk High School. *The Journal of Educational Research*, 102(1), 15–36.

Howe, A. Berenson, S. Vouk, M. (2007). Changing the high school culture to promote interest in information technology careers among high-achieving girls. C. J. Burger, E. G. Creamer and P. S. Meszaros, (Eds). *Reconfiguring the firewall: Recruiting women to information technology across cultures and contexts*, pp. 51-64. Wellesley, Mass: A. K. Peters, Ltd.

Howland, K., & Good, J. (2015). Learning to communicate computationally with Flip: A bi-modal programming language for game creation. *Computers & Education, 80*(Complete), 224–240.

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The Single Sex Debate for Girls in Science: A Comparison Between Two Informal Science Programs on Middle School Students' STEM Identity Formation. *Research in Science Education, 43*(5), 1979–2007.

Jenson, J., & de Castell, S. (2011). Girls@Play: An ethnographic study of gender and digital gameplay. *Feminist Media Studies, 11*(2), 167–179.

Jenson, J. & Droumeva, M. (2016). Exploring media literacy and computational thinking: A Game Maker curriculum study. *The electronic journal of e-Learning, 15*,(2), 111-121.

Jenson, J., & Droumeva, M. (2017). Revisiting the media generation: Youth media use and computational literacy instruction. *E-Learning and Digital Media, 14*(4), 212–225.

Kafai, Y. B., & Peppler, K. A. (2012). Developing gaming fluencies with Scratch: Realizing game design as an artistic process. In C. Steinkuehler, K. Squire, & S. Barab (Eds.), *Games, learning, and society: Learning and meaning in the digital age* (pp. 355–380). New York, NY: Cambridge University Press.

Kafai, Y. B., & Burke, Q. (2015). Constructionist Gaming: Understanding the Benefits of Making Games for Learning. *Educational Psychologist, 50*(4), 313–334.

Koh, A., Repenning, A., Nickerson, H., Endo, Y., & Motter, P. (2013). Will it stick?: Exploring the sustainability of computational thinking education through game design. In Proceedings of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE) (pp. 597–602). New York, NY: ACM.

Kricorian, K., Seu, M., Lopez, D., Ureta, E., & Equils, O. (2020). Factors influencing participation of underrepresented students in STEM fields: Matched mentors and mindsets. *International Journal of STEM Education, 7*(1).

Law, H., & Sikora, J. (2020). Do single-sex schools help Australians major in STEMM at university? *School Effectiveness and School Improvement*, 31(4), 605–627.

Leaper, C., & Starr, C. R. (2019). Helping and Hindering Undergraduate Women’s STEM Motivation: Experiences With STEM Encouragement, STEM-Related Gender Bias, and Sexual Harassment. *Psychology of Women Quarterly*, *43*(2), 165–183.

Madara, D. S., & Cherotich, S. (2016). Challenges Faced by Female-Students in Engineering-Education. *Journal of Education and Practice, 15*.

Male, S. A., Gardner, A., Figueroa, E., & Bennett, D. (2018). Investigation of students’ experiences of gendered cultures in engineering workplaces. *European Journal of Engineering Education, 43*(3), 360–377.

Mozelius, P., & Humble, N. (2023). Educational game design for girls and boys: Towards an inclusive conceptual model for learning programming. *EAI Endorsed Transactions on Creative Technologies, 10*, 1. https://doi.org/10.4108/eetct.4043

Navarrete, C. (2013). Creative thinking in digital game design and development: A case study. *Computers & Education*, 69, 320–331.

O’Connor, P., O’Hagan, C., Myers, E. S., Baisner, L., Apostolov, G., Topuzova, I., Saglamer, G., Tan, M. G., & Caglayan, H. (2020). Mentoring and sponsorship in higher education institutions: Men’s invisible advantage in STEM? *Higher Education Research & Development, 39*(4), 764–777.

Park, H., Behrman, J. R., & Choi, J. (2018). Do single-sex schools enhance students’ STEM (science, technology, engineering, and mathematics) outcomes? *Economics of Education Review, 62*, 35–47.

Professionals Australia. (2015). The Slower Track: Women in the STEM Professions Survey Report. Retrieved from http://www.professionalsaustralia.org.au/professional-women/wp-content/uploads/sites/48/2014/03/2015-Women-in-the-STEM-Professions-Survey-Report.pdf.

Robertson, J. (2012). Making games in the classroom: Benefits and gender concerns. *Computers & Education*, 59, 385–398.

Saffie-Robertson, Ma. C. (2020). It's Not You, It's Me: An Exploration of Mentoring Experiences for Women in STEM. *Sex Roles, 83*(9), 566–579.

Swafford, M., & Anderson, R. (2020). Addressing the Gender Gap: Women's Perceived Barriers to Pursuing STEM Careers. *Journal of Research in Technical Careers, 4*(1), 61.

Wang, M.T., Eccles, J. S., & Kenny, S. (2013). Not Lack of Ability but More Choice: Individual and Gender Differences in Choice of Careers in Science, Technology, Engineering, and Mathematics. *Psychological Science*, 24(5), 770–775.

Werner, L., Denner, J., & Campe, S. (2014). Children Programming Games: A Strategy for Measuring Computational Learning. *ACM Transactions on Computing Education. 14* (4).

ENDNOTES

[1] We recognize that gender is a fluid and variable construct, and decidedly non-binary. The problem is that prior research has aggregated data in terms of biological sex, which came to be referred to as 'gender'. So even though we know these tools are broken, and that binary 'gender' constructs are flawed, we nevertheless need to use them, even as we re-design and rebuild them, in order to learn from and build upon the prior work of others.