Investigating Middle School Students' Early Learning Experience of Computer Science through Creating Apps for Social Good

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ABSTRACT

This study investigated middle school students' learning experiences with a computer science and digital literacy (CSDL) curriculum, which was developed through the CS Pathways researcher-practitioner partnership (RPP) project. The curriculum is based on students learning computer science (CS) through creating apps that serve community and social good. Both quantitative and qualitative data were collected from students in three urban districts: 1) 330 paired pre- and post-survey responses indicating students' confidence and interest in both learning CS and creating apps for social good; 2) 343 open-ended question responses in the post-survey probing into students' perceptions on learning CS after taking the course. Whether there were gender differences emerged from both data were also examined. The results showed that students' confidence in coding and creating apps for social good significantly increased after completing the course, regardless of gender. However, their interest in pursuing CS learning remained at a low level. Further analysis showed male students reported significantly stronger interest than female students. Qualitative analysis of the open-ended responses revealed that both male and female students appreciated the collaborative learning environment and learning coding through making apps. Male students did not like certain instructional approaches that their teachers used. Female students expressed their dislike of coding in general. We applied an interest development theory to further understand these results, which suggested that we consider the trajectory of students' interest development of CS.

CCS CONCEPTS

• Social and professional topics-Computer Science Education; K-12 Education

KEYWORDS: Middle School Students, CS Learning Experience, Creating Apps for Social Good, Gender

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1 BACKGROUND AND MOTIVATION

Computer science (CS) education is important in an increasingly technological world since it helps prepare students to be successful in future careers. A recent US Bureau of Labor and Statistics report projected 1.2 million unfilled jobs requiring CS skills by 2026 [1]. Over the past decade, there has been progress in broadening student participation in computing, but despite these efforts, substantial gaps remain in the ability of CS education to motivate all students equally [10,11]. It is important to learn students' experience of learning CS so that we may improve the curriculum and better engage these students at an early age.

This study is based on a middle school CS project that students learned CS through creating mobile apps that serve social good. It presents the results of student learning experience and seeks to answer the following questions:

RQ1: What were the students' attitude of learning computer science and creating apps for social good? How did their attitude differ by gender?

RQ2: How did students perceive their experience of learning computer science through creating apps for social good?

2 REVIEW OF RELATED WORK

2.1 Students' Confidence and Interest in learning CS

A large body of research has found the need to broaden interest and participation in CS, particularly among traditionally underrepresented groups, such as women [3, 5, 8,13]. Michaelis and Weintrop critically posit that boosting participation alone is not sufficient. The authors encouraged more efforts on developing students' long-term interest in CS [8]. They proposed a deeper integration of student interest development into CS education research by following the Integrated Interest Development for Computing Education Framework. This framework revolves around three dimensions of student interest, namely value, knowledge, and belonging. The authors fan out the three dimensions with factors and examples for future education researchers to follow, so that students may become deeply engaged with CS and educators may design content that reinforces the students' interests.

However, patterns of interest development discovered from former research has not been robustly studied in the contexts of CS learning. Particularly, why do students continue to show low interest in CS despite decades of research and suggested education improvements? In the current study, we use Hidi and Renninger's Interest Development Theory to better understand students' interest in CS [2]. The theory describes interest as a four-phase progression of deepening knowledge and value. The first phase of interest development is a triggered situational interest. If interest is sustained, this first phase evolves into the second phase, situational interest. The third phase, which is characterized by an emerging (or less-well developed) individual interest, may develop out of the second phase. The third phase of interest development can then lead to the fourth phase, a well- developed individual interest. The frameworks show the importance of developing, fermenting, and growing student interest in CS so that it is deep and sustainable. Our project specifically monitors student interest in CS so we may observe the progress and seek to understand what is working in the classroom.

2.2 Gender Difference in Learning CS

Researchers have observed large gender gaps in CS achievement across cultures, where women at Auckland University made up 49% of the total graduates yet only 14% of the CS graduates [5] and that women make up only 18 to 27% of the CS and IT workforce across the USA and Europe [12].

Kelleher et al. studied the use of Storytelling Alice to promote female students' interest in CS [4]. They split an all-female class between Storytelling Alice and a generic control program. Both groups equally achieved basic programming fluency, but students who used the 3D storytelling interface spent 42% more total time programming and were three times more likely to continue coding their programs outside of the workshop time. Wit et al. studied CS interest in Europe [12]. They attributed part of male-female gap in CS to implicit stereotypes among girls about the general attributes of a computer scientist: more likely to be male and play video games. A more recent study found that the gender gap persists across students of color [3]. Researchers have found little meaningful difference in girls' attitudes and self-perceptions about CS between racial groups, implying that actions to develop and retain female interest in CS will apply broadly across all races. In Khan and Luxton-Reilly's study, the authors went further in characterizing the reason why women were underrepresented in New Zealand's CS field [5]. They attributed the gap to a poor student perception about what CS careers entail and the overemphasis of technological backgrounds instead of societal applications. To rectify this, they recommended that CS education include relevant work for social good, motivating CS students in a similar way that medical students may be motivated to find a cure for cancer. Lewis et al. also sought to understand the root causes of male-female disparities through a study of university students across the United States [7]. The finding was that a strong desire to achieve communal goals was inversely correlated with their sense of belonging in a CS field. Female students had a stronger orientation towards communal goals and thus a lower sense of belonging in the CS field than male students.

This body of research presents several different ideas about why the gender gap in CS persists. The examples showing female students' stereotypes about CS and tendency towards communal goals provides support for our project objective of broadening CS participation by creating apps for social and community good.

3 STUDY CONTEXT

The CS Pathways is a research-practitioner partnership (RPP) project with the goal of broadening participation in CS in middle school through students creating apps for social good. The project used code.org' s App Lab as the technology platform. App Lab used block-based programming language to teach the coding concepts and build apps. Through app development using App Lab, teachers can better engage students in project-based and interactive learning of CS.

The project RPP members co-designed the project curriculum [9]. The curriculum is approximately 18-hour. The units are organized into modules, with recommended curated lessons and unplugged activities. The CS concepts in the curriculum include *Events*, *Variables*, *Conditionals*, *Abstraction*, and *Decomposition*. Teachers were given autonomy to implement the curriculum, in which their instruction methods varied and resulted in different timelines, procedures and strategies. Eventually, all teachers started their classes by introducing the impact of computing and apps. They then moved on to code.org' s tutorial of App Lab. After the lesson, most of the students learnt basic event-driven programming by creating an app that navigates between screens. For technology teachers, they predominantly chose to introduce more advanced CS concepts, such as *variables* and *conditionals*. Civics teachers, by contrast, went directly to encourage their students to make apps that can serve their community and culture. Table 1 presents an overview of the curriculum implementation during the 2022-2023 school year.

Table 1. Overview of project curriculum implementation

School	Teacher	Subject	Grade: #Classes	Students
1-A	A	Civics	8^{th}: 2	58
1-B	B	Technology	7^{th} and 8^{th}:10	227
	C	Computer		
2-A	D	Science	8th: 6	140
	E	Civics		
3-A	F	Technology	7^{th}: 10	227
3-B	G	Technology	7^{th}: 10	224
3-C	H	Technology	7^{th}: 10	182
Total			**48**	**1059**

4 METHODS

4.1 Participants

During the 2022-2023 school year, we had 1059 students from three school districts who learnt the curriculum, which provided 423 pre-survey responses (approx. 40%) and 343 post-survey responses (approx. 33%). We paired 330 students' pre- and post-surveys (approx. 31%). Table 2 presents the gender information of the student respondents who completed both pre- and post-surveys.

As shown in Table 2, the large majority of student respondents were either male or female. Due to small sample sizes of other gender categories, our analysis of gender differences focused on male and female students.

Table 2. Surveyed student gender information

Category		N
Gender	Male	164
	Female	147
	Non-binary	5
	Do not wish to say	14

4.2 Data Collection

Both qualitative and quantitative data were collected. For quantitative data, we designed student pre- and post-surveys to inquire about their attitudes and learning experiences of coding and creating apps for community and social good. Both surveys contain the same questions, which mainly focus on three major constructs: 1) confidence in coding and creating apps; 2) interest in coding and creating apps; 3) student perceived ability to create apps in connection with their own interest, culture, and life experience, and serving community and social good. Table 3 shows the survey items.

Table 3. Pre- and post-survey items

Construct	Item
Confidence	Confi_1: I am good at coding. Confi_2: I am good at creating my own apps. Confi_3: I can write code to make an app work Confi_4: If my code doesn't work, I can find my mistake and fix it. : I am good at creating apps to help people.
Interest	Inst_1: I like coding. Inst_2: I like creating apps. Inst_3: I like solving coding problems. Inst_4: I would like to study coding in the future. would like a job that is related to coding.
Creating apps for social good	App for SG_1: I know why Computer Science is important to people like me. Apps for SG_2: I can make apps to share my culture with others. Apps for SG_3: I can use my interests to make apps. Apps for SG_4: I can use my everyday life experience to make apps. Apps for SG_5: At home, I have someone I can talk to ling.

The surveys asked students to rate their perceived ability and interest of CS on a 5-point Likert scale (1 = low or negative, 3 = neutral, 5 = high or positive). In addition, we also added a "no experience" option for all items in both surveys. Our intention was to eliminate bias and increase the survey accuracy, as the option gives students who have no experience with coding and creating apps the opportunity to essentially opt out of the question. Hypothetically, looking for decreased number of "No Experience" in post-survey can provide additional information on whether our project increased the students' access to coding and app creating experience.

We used Cronbach's Alpha to examine the internal consistency reliability measure for the surveys. The results indicate high reliability and consistency (confidence: α = .84; interest: α = .92; perceptions on creating apps for social good: α = .92). Both pre- and post-survey were distributed through Qualtrics to students at their first and last classes respectively.

For qualitative data, the post-survey contains open-ended questions asking students to reflect on what they liked and dislike about their CS course. Eventually, we received 293 valid responses on what the students disliked, and 308 responses on what they liked.

4.3 Data Analysis

The current study followed a convergent mixed-method research design. We conducted quantitative analyses on student surveys to explore the changes of students' attitude and learning experience of CS, defined by their perceived confidence and interest in coding and creating apps, as well as their perceived ability to create apps for social good. Qualitative analysis was employed to further investigate student perceptions.

Before statistical tests, we found out that our dataset was impacted by a large number of students who selected "No Experience" option in pre-survey. To maximize the sample size and ensure test accuracy, we removed the invalid data (including missing values) based on each construct or by each survey item. After the removal by each construct, more than 30% of the total data was removed (52% for confidence, 33% for interest, 13% for CRC). In contrast, when we removed the data by each item, the result improved by 4% to 45%.

Quantitative analysis of student surveys. We conducted both dependent and independent sample t-tests to examine the mean differences of the student respondents. Descriptive statistics were also used to compare the differences. Given the high consistency and reliability of the survey, we compared both sum of the mean scores of each construct and individual mean scores of each survey item in pre- and post-surveys.

Our quantitative analyses followed two steps: First, in order to examine whether students differ significantly in their overall attitude and learning experience, a dependent sample t-test was initially conducted to compare the sum of the mean scores of the three constructs. To gain a better understanding of students' perceptions on the specific items of each construct, the sum mean scores of each item were also compared using the same test method. Second, gender differences were also examined using the both dependent and independent sample t-test holistically and analytically. The dependent sample t-tests can indicate the changes within either gender; the independent t-test then compared the difference between male and female respondents in pre-survey and post-survey respectively. Mean scores by each item were also calculated and compared. All the quantitative analyses described above were conducted using RStudio. In addition to inferential tests, we reported the changes of students that answered "no experience" in pre-survey and post-surveys by each item.

Qualitative analysis of open-ended questions. The open-ended questions were analyzed using an inductive approach. Reflexive thematic analysis (RTA) was applied to initial coding and to establish inter-rater reliability (Braun and Clarke, 2019). The analytic process of the data involved searching repeated and meaningful patterns through researchers' reflective and thoughtful engagement with the data set, such as journaling and writing memos of the coding process. Three researchers worked together to analyze the data and discuss the emergent codes. After initial coding, researchers reviewed and revised the emerging codes for creating categories, merging and splitting codes inductively. Through using RTA, we achieved rich interpretation of the data through collaborative and reflexive processes, rather than seeking consensus on the codes. Additionally, we generated codes for what the students liked and disliked, respectively. We also analyzed and sorted the coding results by gender. Notably, one response may have been coded with more than one code since the students discussed multiple issues in their responses.

5 RESULTS

5.1 Survey Results of Student Attitudes

5.1.1 Overall pre- and post-survey differences

The dependent sample t-test results showed that there were significant increases between the pre-survey and post-survey in students' confidence [pre: M=2.84, SD=0.87; post: M=3.20, SD=0.92; t(157)=-9.89, p< .001] and marginal increases in their perceived ability to creating apps for social good [pre: M=3.24, SD=1.12; post: M=3.32, SD=1.11; t(287)=-2.36, p< .05]. Although no significant differences showed in student interest [pre: M=2.86, SD=1.07; post: M=2.87, SD=1.10; t(220)=-0.35, p >.05], both pre- and post-survey mean scores were lower than the median of the Likert scale, which indicate that students have low interest in computing before and after taking the course.

Given the significant results, we tested on each item of the three constructs. In these tests, we removed the missing values and "No Experience" item by item. The results showed that students' confidence increased significantly in all five items, among which four out of five items changed from negative (below median) to positive (above median). Only when asked about their debugging ability, students rated positive confidence in both the pre-survey and post-survey.

Although showing no significant differences in overall interest, students showed increases in their interest of creating apps (Interest_2) after taking the class. However, their interest and willingness to learn coding in the future significantly decreased (Interest_4). For students' perceived ability to create apps for social good, the marginal increase in the overall test was attributed to students seeing themselves willing to make apps to share their culture with others (Apps for SG_2), and having increased chance of talking about coding at home (Apps for SG_5). In Table 4, we highlighted the significant items.

Table 4. Significant items of pre- and post- surveys (p < .05)

Confidence	N	Pre-		Post-		*t*
		M	SD	M	SD	
Confi_1	231	2.77	0.76	3.12	0.92	-5.76
Confi_2	193	2.50	0.85	3.04	0.93	-6.88
Confi_3	197	2.86	0.99	3.33	1.02	-5.42
Confi_4	296	3.13	1.04	3.43	0.94	-3.35
Confi_5	186	2.61	0.87	3.00	0.91	-4.60
Inst_2	233	2.98	1.06	3.13	1.12	-2.24
Inst_4	299	2.83	1.13	2.55	1.09	4.96
Apps for SG_2	288	3.33	1.04	3.53	0.99	-2.84
Apps for SG_5	288	2.65	1.20	2.85	1.28	-2.72

To further understand the results, we then analyzed the changes based on gender. The goal is to further identify the source of differences.

In addition, we calculated the number of students who reported "No Experience" on their confidence of coding, creating apps, and creating apps to help others in both pre- and post-surveys as shown in Table 5. The results showed that the number of students reported "No Experience" greatly decreased. As expected, creating apps and creating apps to help others experienced the greatest decline. The post-survey mean scores were also reported in the table, but the scores remained below the Likert median (m = 3).

Table 5. Number of no experience in pre- and post-survey

Confidence	Pre-survey N	Post-survey	
		N	M
Confi_1: I am good at coding	66	15	2.89
Confi_2: I am good at creating apps.	104	22	2.96
Confi_5: I am good at creating apps to help others.	110	28	2.75

5.1.2 Comparison by gender

Dependent sample t-test on each gender group was first conducted to examine pre- and post- survey difference within each gender group. Table 6 presents the mean differences of pre- and post-survey of each gender group. The results indicate that both male and female students' confidence significantly increased, but their interest and creating apps for social good presented no significant changes.

Second, the cross-gender comparisons of pre-survey and post-survey were conducted using independent t-test. There was no significant difference between male and female on their confidence in the pre-survey [*diff.* =-0.06, p > .05], whereas male students showed significantly higher mean score than female in the post-survey [*diff.* = 0.27, p < .001]. Independent t-test results indicated that male students' the overall interest of CS were higher than that of female students in both pre-survey [*diff.* = 0.38, p < .0001] and post-survey [*diff.* = 0.39, p < .0001]. Males were showing more positive interest than females both before and after the course. This result indicates that the low interest of all students was due to female students.

Further examination of student interest by item showed that male students showed positive attitudes in coding, debugging, learning coding in the future and doing coding related work in the future. Female students showed extremely negative interest (pre: M = 2.2, post: M = 2.1 post) when asked whether they want do coding-related job in the future.

Table 6. Pre- and post- student attitudes by gender

		Male (90)			Female (79)		
		Pre-	Post-	*t*	Pre-	Post-	*t*
Confidence	M	2.99	3.38	-8.23	2.93	3.11	-3.55
	SD	0.98	0.92		0.88	0.94	
Interest	M	3.03	3.06	-0.80	2.66	2.67	-0.20
	SD	1.10	1.07		1.02	1.09	
Creating apps for social good	M	3.59	3.52	-1.29	3.45	3.50	-1.63
	SD	1.03	1.01		1.03	1.03	

5.2 Students learning experiences

5.2.1 All Students' learning experience

Students' expressions of what they did or did not like about the course and CS were ambivalent. In general, we identified 6 major themes with sub-themes indicating the students' least interested parts of learning coding and making apps for social good, as presented in Table 7. Among all, the number one rated least interested aspect is coding, among which students complained mostly about coding/programming to make apps. Some students were overwhelmed by coding, mainly because they think coding is "time-consuming", "confusing", and "have difficult with debugging". One student mentioned that coding may not be useful or relevant to his/her.

"*My least favorite part of this class was learning how to code, I feel like it was challenging and complicated. And I don't think I am going to go into a major that has something to do with coding.*"

"*The problems I had when coding, it was difficult and hard not to give up when a problem occurred in my coding process.*"

The second least favorite of their learning experience was regarding classroom instruction. Mostly, students complained about their teachers' choices of resources being boring. Besides, they also did not want their work to be assessed. Some students felt the teacher took too long at the beginning of the course to give them hands-on experience.

"*The due date was stressing me out. Also, the fact that we had a requirements sheet.*"

"*Maybe that we had to watch a lot of Brainpops and Edpuzzles to actually learn about computers.*"

Notably, among all answers of least favorites, we noticed a number of positive responses and some complains we think are "good problem to have". For example, there were 44 students that replied "Nothing" about the course they did not like. Another 15 students expressed that they wished for more time to work on their apps.

Table 7. Students' least favorite parts of the course

Dislike: Main themes	Sub-themes	No.
All of it		13
Nothing		44
Coding Experience	coding app	46
	debugging	26
	time consuming	9
	not enough time	15
	Total	**96**
App Creation	no interest	33
	tool	1
	app design	15
	Total	**49**
Classroom Instruction	instruction approach	22
	instructional resource	25
	the curriculum	12
	unplugged activity	4
	Total	**63**
Classroom Community	partnership	15
	teachers' attitude	3
	Total	**18**

When asked what their **most favorite parts** about the course, the students' responses followed five main themes, as shown in Table 8. The responses were dominated by collaboratively creating apps with their peers. Students further expressed that making apps gave them chance to express their ideas freely.

"*My favorite part of this class is that I get to make my app depending on my interest and what I want others to learn, see, and do when on my app.*"

Table 8. Students' favorite parts of the course

Like: Main themes	Sub-themes	No.
Nothing		25
Coding Experience	learning to code	65
	debugging	8
	Total	**73**
App creation	app design	18
	making real app	98
	helping others	8
	presenting the app	16
	Total	**140**
Classroom Instruction	instruction approach	44
	instructional resource	20
	unplugged activity	6
	Total	**70**
Classroom Community	collaboration	57
	the instructor	5
	Total	**62**

5.2.2 Students' learning experience by gender

We further analyzed both negative and positive responses in terms of gender. For positive responses by gender, 23% male and 21% female students expressed their interest in creating apps. Male (17%) also showed stronger interest in coding than females (6%). The differences between male and female students in regard to coding experience is that male students appreciated the new experience from coding.

"My favorite part of class is when we get to try different activities like coding and learning about coding, and how it works."

In addition, among the sub-themes of what male and female like about app creation, more female students stated that they like creating apps to help others than male students.

"…learning to make a change in the world"

"…trying to help decrease homelessness and reaching out to guest speakers"

For negative responses, male and female students presented great disparities. Male students did not like the instruction approaches and materials their teachers used. Males especially did not want their apps being assessed. They were eager for hands-on coding experience to be challenging, and they did not seem to be interested in their teachers using some videos talking about the importance of CS. More than one third of the female students reflected negatively on coding. Most female students did not specify the reasons that they did not like coding, but mentioned "*no interest in coding*".

6 CONCLUSION AND DISCUSSION

In this study, we investigated the middle school students' experiences and perceptions in learning computer science through creating apps for social good. The quantitative results showed that both male and female students increased their confidence of coding and creating apps for social good after taking the course. However, no significant changes in interest were found for both gender groups. Males entered the course with positive and higher interest than female who presented negative interest. Both genders showed negative interest in pursuing a career in CS, with females being notably lower than males. Students perceived that their ability of creating apps for social good increased marginally, as they saw themselves connecting app creation to their culture and serving their community. Qualitative analysis of the open-ended responses probing into students' perceptions of their favorite and least favorite parts of course reveal that the majority of students appreciated the collaborative learning environment and learning coding through making apps. Male students did not like certain instruction approaches that their teachers used. Female students expressed their dislike of coding in general.

Most concerningly, the result showed student interest in CS did not increase even when their confidence about coding did. This aligns with our prior study and other research studies [6, 9]. In this paper, we applied Interest Development Theory to interpret the significant result. Basically, we did not find evidence from the quantitative analysis showing the transitional change of students' interest from situational to individual. Unfortunately, both male and females showed negative interest in pursuing a career in CS, which indicated no emergent or well-established individual interest. However, males showed higher incoming interest in terms of coding and creating apps, which implied that they had higher trigged situational interest than females. The qualitative data provided a more positive insight. When asked about favorite parts of the class, approximately 30% of students expressed explicitly that app creation was their favorite part of the class, which indicated the course triggered students' interest. However, there was still no evidence from qualitative data proving that sustaining individual interest developed. Students even stated that they do not think they will "major in CS" or "find its useful in the future." The holistic results confirmed that the gender gap in CS interest between male and female students still persists, despite our curriculum focused on creating apps for social good.

These results further demonstrated the need for classes to generate deep and long-lasting interest in CS that transcends simply doing well on the classroom assignments. Research needs to further develop strategies that can move female students' CS interest to individual level that they may consider it as a career. Taken collectively, these results show both promise and peril for closing the gender gap in CS participation. Our curriculum was clearly effective at improving students' confidence in coding and app creation, but overall interest in CS and interest in creating apps for social good only marginally changed.

7 LIMITATION AND FUTURE RESEARCH

While we have observed some significant preliminary results in student learning experiences, there are some limitations. First, a large amount of data was removed due to the "No Experience" option. To improve this situation, we will modify our surveys. Second, we did not find quantitative evidence of interest development. In the future, we will modify our survey based on the Interest Development Model for better investigation of the students' interest development trajectory. Last, we realized the study did not take teachers' instruction methods into consideration, which may have a large impact on students' learning experience. Therefore, for future study, we will examine the impact of teachers' instruction methods on their students' learning experience.

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