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Examining Gender Difference in the Use of ScratchJr in a Programming Curriculum for First Graders

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ABSTRACT

Background and Context: Historically, women have been underrepresented in computer science. To address this gender gap, researchers advocate for high-quality computer science programs for early childhood.

Objectives: This study examines gender differences in coding performance before and after implementing a 24-lesson visual programming curriculum using ScratchJr. The curriculum's key features are summarized based on teachers' observations of student reactions.

Method: Using a mixed methods approach, the study employs quantitative analysis to assess gender differences in pre and post assessments, while qualitative analysis explores the impact of the curriculum on girls' and boys' coding performance.

Findings: The findings reveal comparable coding proficiency between boys and girls. Teacher interviews highlight aspects of the curriculum that reduced gender stereotypes, such as student engagement, autonomy, debugging practice, and collaborative exploration.

Implications: Policymakers should prioritize high-quality computer science programs in early childhood to combat gender-interest stereotypes and promote confidence, emotional strengths, perseverance, and collaboration through open-ended coding projects.

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ScratchJr; Programming; Curriculum implementation; Gender difference; First-grade

Women are underrepresented in computer science careers. For example, the United States Census Bureau statistics indicate that only about 25% of computer scientists and 15% of engineers were women (Martinez & Christnacht, 2021). Previous work shows that men develop programming skills easier than women in higher education (Kiss, 2010; Wilcox & Lionelle, 2018). While some research shows that college students who are already in computer science programs do not show significant differences in their programming performance, other factors such as prior experience, confidence, and attitude still show differences (Baser, 2013; Rubio et al., 2015; Wilson, 2002). It is worth mentioning that such attitudes and affect differences between men and women were also found in other subject domains such as mathematics despite gender itself did not contribute to performance difference (Else-Quest et al., 2010; Hyde et al., 2008; Lindberg et al., 2010). Wilcox and

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Lionelle (2018) reported that students with prior experience outperform students without prior programming experience in a college introductory CS course. This is of concern since the majority of female students do not have prior programming experience.

Similarly, when studying secondary school students, Bruckman et al. (2002) reported that gender itself is not a significant predictor of programing achievement; however, factors such as prior programming experience and time spent on programming are significant predictors. Bruckman et al. (2002) further pointed out that boys tend to be better at these significant predictors of programming than girls. Children's interests directly contribute to the time they spend on coding activities. Additionally, Witherspoon et al. (2017) reported that female middle school students have less prior programming experience than their male counterparts. This aligns with several studies that found that boys have more confidence than girls in STEM (Atmatzidou & Demetriadis, 2015; Nourbakhsh et al., 2004; Witherspoon et al., 2017). Therefore, Bruckman et al. (2002) suggested that "educators wishing to increase gender equity in technical skills should focus on strategies for foster interest among girls" (p. 119). This suggestion is confirmed by the study of gender-interest stereotypes by Master et al. (2021). Master et al. (2021) found that children were influenced by cultural stereotypes: students as young as first grade (six years old) showed the stereotype that girls are less interested in computer science and engineering than boys. The experimental study by Master et al. (2021) showed the destructive effect of endorsing such gender-interest stereotypes: when girls were told that boys were more interested in certain activities (e.g. computer science and engineering activities), only 35% of girls chose the activity; whereas when girls were told that girls and boys were equally interested in these activities, 65% of them chose the activity.

Master et al. (2021) suggested to educators and parents that high-quality computer science programs for early childhood are needed to counteract gender-interest stereotypes and gender-stereotypes in computer science. Likewise, Sullivan and Bers (2013) developed a program for introducing girls to programming and robotics in early childhood before students internalize the gender stereotype. Several studies that investigated students' attitudes after implementing programming software to middle school students, show consistent results that no significant gender difference was found (Gunbatar & Karalar, 2018). This suggests that teaching programming to students may close the gap between gender differences (Su et al., 2014; Zuckerman et al., 2009). Furthermore, Denner et al. (2012) and Monroy-Hernández and Resnick (2008) introduced a visual programming environment to provide opportunities for girls to engage with programming and develop positive attitudes towards programming. This is consistent with Sullivan's (2016) finding that personal enjoyment contributes to young children's perception of gender appropriateness of technologies.

In examining gender differences in Kindergarteners' robotics and programming achievement, Sullivan and Bers (2013) proposed that introducing STEM concepts at a very early age and providing opportunities for both boys and girls to succeed in the traditionally masculine areas such as robotics and programming can serve to avoid long-lasting gender stereotypes. In their work, Sullivan and Bers (2013) found that both boys and girls were able to successfully complete their program.

Following this line of research, in this study, we are examining how the implementation of a 24-lesson visual programming curriculum that uses ScratchJr, Coding as Another Language (CAL) for ScratchJr ("CAL-ScratchJr"), impacted boys' and girls' performance in programming. We hypothesize that both boys and girls will be equally, positively impacted by the curriculum implementation.

Coding as Another Language (CAL) for ScratchJr curriculum

Coding as Another Language for ScratchJr ("CAL-ScratchJr") is a set of curriculum units for kindergarten, first grade, and second grade that connect the natural language with programming language for teaching coding in early childhood with ScratchJr (Bers, 2019; DevTech Research Group, 2023). Each grade-level curriculum consists of 24 lessons of 30 to 45 minutes that engage young children in developing computational thinking, problem-solving, and collaboration skills while learning how to create their interactive projects with ScratchJr. The CAL-ScratchJr curriculum is freely accessible (DevTech Research Group, 2023).

ScratchJr

ScratchJr is a free, introductory computer programming language that is available on iPads, Android tablets, and Chromebooks. ScratchJr was developed by the Developmental Technologies (DevTech) Research Group in collaboration with the MIT Lifelong Kindergarten Group, and the Playful Invention Company. It is a graphical block-based programming language that was specifically designed to fit the developmental needs of young children (ages 5–7) (Bers & Resnick, 2015; Flannery et al., 2013; Sullivan & Bers, 2019). ScratchJr remains one of the most widely-used visual programming tools for young children.

Six different types of blocks (Triggering, Motion, Looks, Sound, Control, and End) are intentionally designed in puzzle shapes and with different colors in ScratchJr (see these types of blocks in the example interface in Figure 1). ScratchJr executes commands from left to right given by these blocks. Particularly, there are five Triggering blocks function to start a program (e.g. Tap block, Messenger block) with yellow color; eight Motion blocks function to move characters (e.g. Right block, Up block) with blue color; six Looks blocks function to change characters' appearance (e.g. Grow block, Shrink block) with purple color; two Sound blocks function to play or record sound (e.g. Pop block and Record block) with green color; six control blocks function to control parts of a program (e.g. Wait block and Repeat block) with orange color; finally two End blocks including end and end with repeat blocks that are in red. Figure 1 below presents an example interface of the ScratchJr App. For more information about ScratchJr, please see scratchjr.org. ScratchJr was the programming language taught and used in the study described in this paper.

Purpose of this study

The purpose of the study is to examine the impact of exposure to early programming through the CAL-ScratchJr curriculum on boys' and girls' knowledge about coding and computer programming. To accomplish this purpose and to further understand the key features in the curriculum that may engage students in

Figure 1. An Example ScratchJr Interface.

programming, this mixed methods study examines the programming skills of both boys and girls before and after the curriculum implementation, the complexity of the programming projects created during the course of the curriculum, and teacher's comments about student's reactions to a different aspect of the curriculum.

In this mixed methods study, we explored the following four research questions:

(1) Is there a baseline gender difference in students' coding performance, as measured by the validated Coding Stage Assessment (CSA) before the implementation of the curriculum?
(2) To what extent does participation in the CAL-ScratchJr curriculum affect children's coding performance, as measured by CSA after the intervention?
(3) Is there a significant difference in coding performance between boys and girls, as measured by their CSA scores after the intervention, as well as their scores on the three ScratchJr projects during the curriculum intervention?
(4) What specific attributes of the CAL-ScratchJr curriculum may have contributed to the observed findings?

Methods

This section outlines the research methods used for answering the research questions pertaining to this study, as well as a description of the participants and sampling, a description of the instruments that are used in this study, an outline of the procedures of data collection, and data analysis.

Research design

This study employs a mixed methods design. Mixed methods research comprises the collection and analysis of both quantitative and qualitative data (Creswell, 2014; Creswell & Clark, 2011). Mixed methods research is defined as "research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of inquiry" (Tashakkori & Creswell, 2007, p. 4).

An embedded mixed methods design with predominant quantitative and supportive qualitative approaches serves as a model for this study. The study involved independent and concurrent collection of QUAN and QUAL data, which were analyzed separately. The QUAN data were used to answer the first three research questions, while the QUAL data were used to address the fourth question.

Participants and sampling

Participants in this quantitative phase were first-grade students coming from six different classrooms within two different schools. Participants from Classroom 1, 2, and 3 came from a public school in a mid-size city in Arkansas and Classroom 4, 5, and 6 came from a public school in a remote rural setting in Minnesota in the United States. A total of 72 students were included in the analysis (35 females and 37 males). Participants in the qualitative phase were the six teachers in these six classrooms from School 1 in Minnesota and School 2 in Arkansas. All these six teachers are female teachers; of those, five reported their race as white and one did not report. Among five who reported years of experience, four teachers have around 5 years of teaching experience, one teacher reported 31 years of experience. None of these teachers had previous ScratchJr experience while two teachers from School 1 and one teacher from School 2 reported having previous coding experience.

Measures

The quantitative phase of this mixed methods study involves students' coding assessment before and after the curriculum using the CSA, as well as evaluating the three ScratchJr projects created by the children during the curriculum implementation.

Coding Stage Assessment (CSA)

CSA is a validated instrument used to assess learners' coding stage in ScratchJr (de Ruiter & M. Bers, 2021). As Sullivan and Bers (2019) postulated, just like literacy has stages when a child learns to read and write, there are also five coding stages when learners learn to code. These five stages progress from Emergent, Coding and Decoding, Fluency, New Knowledge, and all the way to Purposefulness (see an example question from Fluency in Figure 2). The CSA's objective is to determine the child's current stage of proficiency by asking them six questions from each stage, covering concepts such as sequencing, events, loops, and parallel programming, which are integrated into ScratchJr. The assessment is administered synchronously via Zoom by well-trained research assistants who share a visual prompt

Q3.1: Make this program.
Please change the program so that Cat will make a pop noise 4 times, and move forward 4 times, but **only** say Hi **once**.
Rephrase: Right now Cat says hi 4 times, how can I change it to only say Hi one time?

- Satisfactory: Child moves hi block outside of repeat loop
- Unsatisfactory: Child does not move the hi block out of the repeat loop or removes the entire repeat loop without changing parameters appropriately

Figure 2. An example CSA assessment question.

window for each question and narrate it to the student. The students then code in ScratchJr on their device and present their work via Zoom, with verbal explanations where applicable. The research assistants rate the student's response to each question as either satisfactory or unsatisfactory. To progress to the next stage, the student must answer at least five out of six questions satisfactorily in one stage. The student's coding stage is determined by the last stage they passed, and the total score is calculated by giving more weight to higher stages, with a maximum possible score of 39 points.

Well-trained assessors administered the CSA to these first graders before and after the curriculum implementation (pre-CSA and post-CSA). All research assistants completed CSA training and passed a quiz on this instrument before administering it. To further ensure inter-rater reliability, 20% of students were randomly assigned a second rater, and the data in this study indicated a substantial interrater reliability (Cohen's $\kappa = 0.85$). Detailed description of the CSA instrument can be found from the official DevTech Research website: https://sites.bc.edu/devtech/research/validated-research-instruments/scratchjr-instruments/csa-scratchjr/

ScratchJr project score

The ScratchJr Project Score is generated by using the ScratchJr Project Rubric, which is a validated assessment tool that measures children's ability to transform their coding knowledge into purposeful and creative projects (Unahalekhaka & Bers, 2022). The rubric consists of six components (e.g. sequencing, repeats, etc., ranging from 0 to 4 points) in coding concepts with a cap of total 24 points and seven components (e.g. character or background customization, use of sound function, etc., ranging from 0 to 4 points) in creativity with a cap of total 16 points. Therefore, the rubric has a total maximum of 40 points for a project. An example component of the rubric is shown in Figure 3. The ScratchJr Projects were collected at the beginning (time 1), the middle (time 2), and end (time 3) of the curriculum implementation.

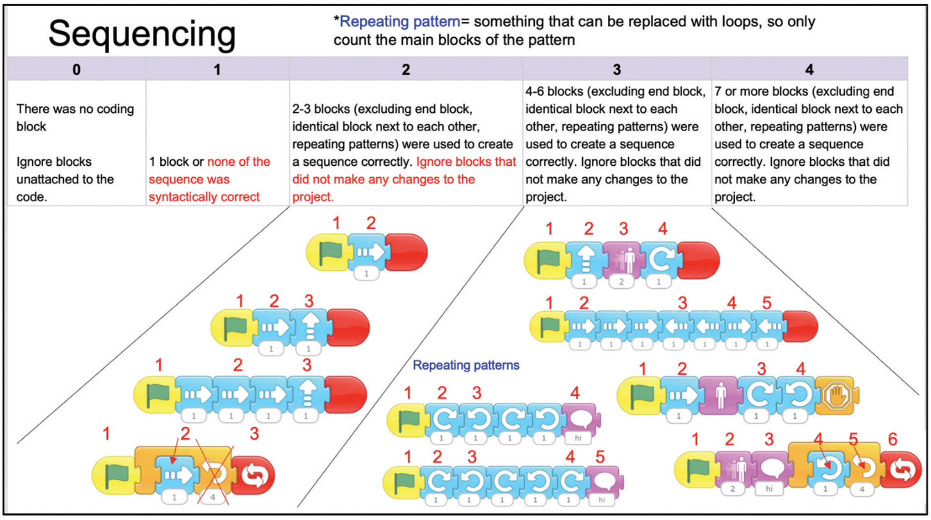

Figure 3. An example component of scratchJr project score rubric.

Intervention–The CAL-ScratchJr curriculum

The CAL-ScratchJr curriculum implemented in this study was designed for first-grade participants and focused on coding projects related to books, both fiction and non-fiction. Figure 4 illustrates a visual overview of the curriculum roadmap, developed by DevTech Research Group (2023). The curriculum includes coding projects based on two books: a non-fiction book about Ada Byron Lovelace, a pioneer woman in computer science, and a fiction book, Where the Wild

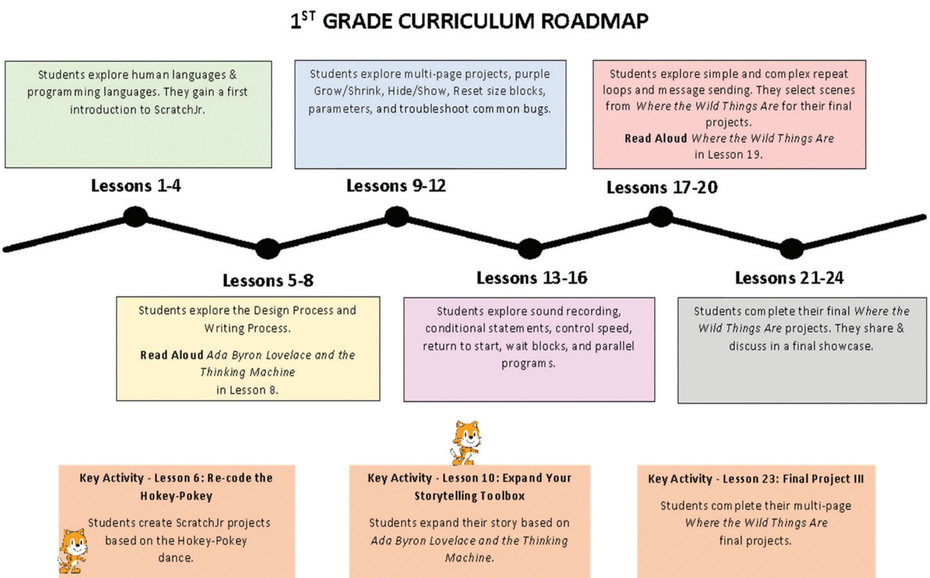

Figure 4. A visual road map of the first grade CAL-ScratchJr curriculum.

Things Are by Maurice Sendak. After reading the non-fiction book, children are tasked with recreating the sequence of events in Ada's life using ScratchJr. For the fiction book, children create their own interactive dancing monsters inspired by the wild rumpus organized by the monsters in the book. Teachers are encouraged to substitute any of these books with their favorites, as long as they have a clear sequencing of events. Children create their own endings for their books and learn how to retell the stories in creative ways using the animations they programmed in ScratchJr.

The DevTech Research Group (2023) outlines the typical structure of a CAL-ScratchJr lesson, which consists of six activities: Warm-Up, Opening Tech Circle, ScratchJr Time, Unplugged Time, Word Time, and Closing Tech Circle. Warm-Up activities aim to introduce or reinforce computational concepts such as algorithms and repeat loops through face-to-face games, stories, or songs. The Opening Tech Circle is a group activity where students discuss the relevant concepts in the lesson. ScratchJr Time is dedicated to introducing coding skills using the ScratchJr programming language. Unplugged Time includes games and activities that promote movement and social interaction among students while further exploring computational concepts. Word Time introduces concepts and ideas from literacy, linking them with computer science concepts. Finally, the Closing Tech Circle is an activity where students reflect on the concepts they have learned in the lesson.

The CAL-ScratchJr curriculum in this study is grounded in seven powerful ideas of computer science (CS) inspired by Papert (1980), namely algorithms, design process, representation, debugging, control structure, modularity, and hardware/software (DevTech Research Group, 2023). These powerful ideas are integrated with basic concepts in literacy and math in the curriculum. For instance, the powerful idea of *algorithms* emphasizes that order matters, and the CAL-ScratchJr curriculum uses this idea to align sequencing in literacy and counting and patterns in math with CS concepts. The powerful idea of *design process* is integrated into the curriculum with activities that involve imagining, planning, revising, and sharing, and are aligned with the writing process in literacy and problem solving in math. The powerful idea of *debugging* is emphasized in the curriculum to help students analyze, test, and evaluate their coding blocks when miscommunications occur. This idea is aligned with literacy in terms of editing and audience awareness and aligned with math in terms of error checking and problem analysis. Teachers are provided with explicit connections between the powerful ideas of CS and each lesson in the curriculum. The CAL-ScratchJr curriculum integrated all these seven powerful ideas via ScratchJr, which includes features that enable the realization of these ideas. For example, ScratchJr provides means of self-expression (i.e. allows children to create animated stories in an open-ended manner), introduces and encourages debugging and problem-solving (i.e. prompts problem-solving with complex concepts such as loops and control flow), and provides a low-floor and high-ceiling interface (i.e. a child can easily start by just making one character move and then go on to create complex multi-character, multi-page projects).

The CAL-ScratchJr curriculum promotes opportunities for open-ended exploration, creation of personally meaningful ScratchJr projects, imagination, problem-solving, conflict resolution, and collaboration by engaging children in six positive behaviors described by the Positive Technology Development (PTD) theoretical framework (Bers, 2012):

content creation, creativity, choices of conduct, communication, collaboration, and community building. By simply dragging various graphical programming blocks to create their own animated stories and games, young children learn the fundamental computational concepts such as sequences and loops and gain opportunities to explore powerful ideas of computer science such as algorithms, modularization, and control structure. For example, children can snap together graphical programming blocks to make characters move, jump, dance, sing, and repeat certain motions with a control structure block; they can add additional characters and/or scenes to make animation for the added characters based on the first character's message using Messenger block. Additionally, children can modify characters in the paint editor, add their own voices and sounds, even insert photos of themselves, then use the programming blocks to make their characters come to life! Each CAL-ScratchJr lesson offers activities for the whole group, such as singing and dancing the Hokey-Pokey, and activities for small groups or individuals, such as writing on design journals.

All of these CAL-ScratchJr activities offer opportunities for socio-emotional development in the context of a collaborative play-based learning environment, a coding playground, in which there is a purposeful exploration of ethical and moral values and intentional promotion of character strengths introduced as Coding as Palette of Virtues (Bers, 2021). Each lesson in the CAL-ScratchJr curriculum intentionally lists these relevant PTD components and Palette of Virtues for teachers, for example, in Lesson 3, in which children explore the connection between natural and artificial languages, the connected PTD is content creation and community building; and the connected Palette of Virtues are optimism, curiosity, and fairness.

Data collection

Prior to data collection, the study protocol was reviewed and approved by the Institutional Review Board of the authors' affiliations. Written informed consent was obtained from parents of all participating first-grade students.

To assess students' coding proficiency in ScratchJr, well-trained research assistants administered the validated CSA instrument explained above to each student individually via Zoom. Additionally, ScratchJr projects created by children at three points in time were also collected. Teachers shared the consented student's ScratchJr Projects via secured online storage such as Google Drive and Box. Well-trained research assistants then scored each ScratchJr project according to the ScratchJr Project Rubric (Unahalekhaka & Bers, 2022). These scored ScratchJr projects provided another form of quantitative data to this study.

For the qualitative data collected from teachers, we used semi-structured interviews as the form of data source that allows a variety of responses (e.g. Now that you've completed the full coding curriculum, what would you say are the highlights of your experience? and What else would you like to share?). The participants were contacted and informed about our study. Six first-grade classroom teachers who taught the student participants in the quantitative phase of the study were invited to participate in the qualitative phase. According to Patton (1990), qualitative research does not require a large sample. Purposeful small samples, or even single cases, can be information-rich. By interviewing these six classroom teachers who had implemented the curriculum in their classrooms, we explored their perceptions about students' reactions to the curriculum and the contributing factors to the effectiveness of such a curriculum for both girls and boys.

A letter explaining the study and details about the interviews was sent ahead of time, including the consent forms. One designated researcher met with each participating teacher synchronously via Zoom at the interviewee's convenience after the curriculum implementation. The interviews for this study were conducted in English and lasted approximately 30–45 minutes. All the interviews were audio-recorded after getting permission from each participant and then transcribed verbatim for data analysis.

Data analysis

Data in the quantitative phase were analyzed using the statistical software R, and descriptive statistics including means and standard deviations were reported. The goal of these descriptive statistics is to better communicate the results, and provide a basis for analyzing the specific research questions (Teddlie & Tashakkori, 2009).

To address the first three research questions, we conducted the following quantitative analyses:

1.To determine if there is a baseline gender difference in students' CSA scores, we used the Mann-Whitney U Test to compare the pre-CSA scores of girls and boys.

2.To determine if the CAL-ScratchJr curriculum had an impact on students' CSA scores, we used the repeated measure t-test to compare pre- and post-CSA scores.

3.To examine if boys and girls performed differently on the CSA and ScratchJr Project scores after participating in the curriculum, we used the Mann-Whitney U Test for post-CSA scores and the Independent Samples T-Test to compare ScratchJr Project scores at the beginning, middle, and end of the curriculum.

Data analysis in the qualitative phase was done by coding and thematic analysis across cases to address the fourth research question.

4.To answer what attributes of the CAL-ScratchJr curriculum might have contributed to the quantitative findings, coding and thematic analysis were used as mentioned above.

Data analysis in qualitative research consists of preparing and organizing the data (i.e. text data as in transcripts, or image data as in photographs) for analysis, then reducing the data into themes through a process of coding and condensing the codes, and finally representing the data in figures, tables, or a discussion (Creswell, 2007, p. 148). For this study, a designated researcher transcribed verbatim the audio-recorded interviews into Word processing software.

The authors initially analyzed the transcriptions through open coding. Specifically, we examined the teachers' responses, identified significant statements, sentences, and quotes that conveyed students' experience with the CAL-ScratchJr curriculum from the interviews, and we highlighted the repeated words (or keywords in-context). The significant statements, sentences, and quotes were then categorized under themes and sub-themes. All authors reached consensus on the main themes first. Themes were named by each author of the study respectively, then, they discussed and came up with consistent names of the themes together. Researcher triangulation, peer debriefing, and team consensus on themes were done to ensure the credibility of the qualitative findings. After reviewing the data gathered, we analyzed the responses based on the research question. The first author coded the interview data collected, and each code was

Table 1. Summary of the research questions.

Research Question	Data Source	Data Analysis Technique
Is there a baseline gender difference in students' coding performance, as measured by the validated Coding Stage Assessment (CSA) before the implementation of the curriculum? (QUAN.)	Pre-CSA; Gender Information	• Descriptive analysis • Mann-Whitney U Test
To what extent does participation in the CAL-ScratchJr curriculum affect children's coding performance, as measured by CSA after the intervention? (QUAN.)	Pre-CSA; Post-CSA	• Descriptive analysis • Paired Samples T Test
Is there a significant difference in coding performance between boys and girls, as measured by their CSA scores after the intervention, as well as their scores on the three ScratchJr projects during the curriculum intervention? (QUAN.)	Post-CSA; ScratchJr Project Scores (time 1, time2, and time3); Gender Information	• Descriptive analysis • Mann-Whitney U Test • Independent Sample T Test
What specific attributes of the CAL-ScratchJr curriculum may have contributed to these findings? (QUAL.)	Teacher Interviews	• Thematic analysis

symbolized with a unique identifier, such as S01T01 for the interview with teacher #1 from school #1 and S02T03 for the interview with teacher #3 from school #2.

To illustrate the data analysis as a whole, we outlined the summary of what data sources were used and how data were analyzed to answer each research question (see Table 1).

Results

Quantitative phase results

To address the first research question regarding gender differences in students' baseline CSA coding scores, we begin by presenting the baseline descriptive statistics of CSA scores by gender in Table 2 below. Additionally, to explore potential disparities between boys and girls in their initial CSA scores, Shapiro-Wilk tests were conducted to assess the normality of the pre-CSA data for each gender. However, the results revealed a deviation from the normality assumption. In Figure 5 below, we illustrate the distribution of pre-CSA scores for girls and boys. Consequently, the Mann-Whitney U test was employed to ascertain whether significant differences existed between boys and girls in their baseline CSA scores. Notably, the findings indicate that there are no significant disparities between boys and girls in their baseline CSA scores (Mann-Whitney $U = 755$, $p = 0.2$).

The second research question aims to explore the impact of implementing the CAL-ScratchJr curriculum on children's CSA scores in ScratchJr. Descriptive statistics capturing the changes in CSA scores after the curriculum implementation are presented in Table 3.

Table 2. Descriptive statistics of pre-curriculum CSA scores.

	Pre-CSA Score				
	N	Min.	Max.	*Mean*	*SD*
Boys	37	0.0	11.7	4.0	2.8
Girls	35	1.1	11.7	4.3	2.7

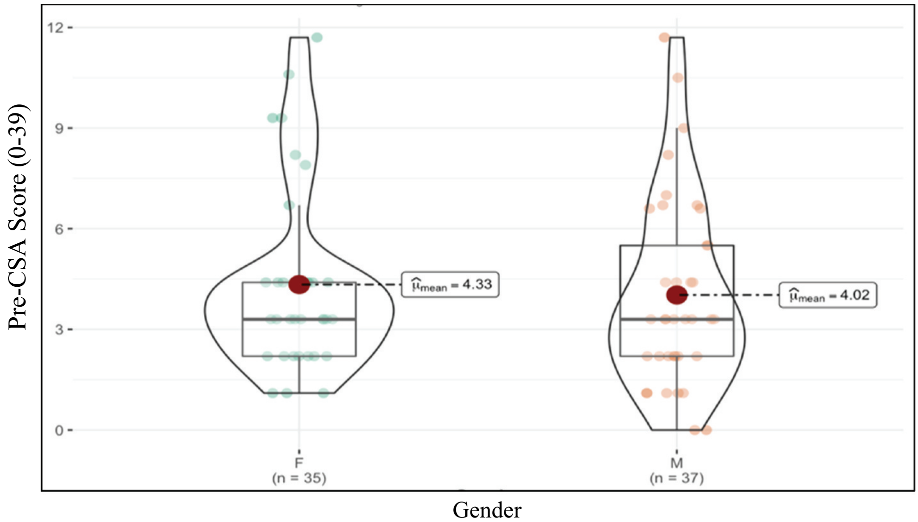

Figure 5. Distribution of girls' and boys' pre-CSA scores.

To ensure the robustness of our findings, Shapiro-Wilk tests were conducted to assess the normality assumptions of the CSA difference scores before and after the curriculum implementation for both boys and girls. The results indicated that the normality assumptions were satisfied in both groups. To further investigate whether boys and girls exhibited significant changes in their CSA scores following the curriculum implementation, repeated measure t-tests were employed. Notably, the results revealed significant improvements in CSA scores for both boys and girls with the CAL-ScratchJr curriculum implementation, as confirmed by the repeated measure ($t(36) = 13.92$, $p < 0.001$; $t(34) = 10.06$, $p < 0.001$). Specifically, girls showed an average increase of 11.9 ($SD = 7$), while boys showed an average increase of 10.4 ($SD = 4.5$) in CSA scores out of 39.

The third research question aims to examine potential performance differences between boys and girls in CSA scores and three ScratchJr Project scores following the implementation of the CAL curriculum. Descriptive statistics for these measures can be found in Tables 4-7. The analysis included post-CSA scores for all participating boys and girls, as well as ScratchJr Project scores for boys ($n = 35$) and girls ($n = 32$) at each time point, with slight variations in sample size due to occasional student absences during specific projects. Notably, after receiving the CAL curriculum, boys and girls demonstrated comparable performance in CSA scores and ScratchJr Projects.

To ensure the validity of our findings, we examined the normality and homogeneity of variance assumptions for CSA scores and ScratchJr Project scores. Shapiro-Wilk tests

Table 3. Descriptive statistics of change of CSA Scores after the Curriculum.

	CSA Difference Score				
	N	Min.	Max.	*Mean*	*SD*
Boys	37	1.1	19.8	10.4	4.5
Girls	35	−1.1	26.7	11.9	7.0

Table 4. Descriptive statistics of post-curriculum CSA Scores.

	Post-CSA Score				
	N	Min.	Max.	*Mean*	*SD*
Boys	37	4.4	22.1	14.4	5.1
Girls	35	3.3	29.0	16.2	6.8

Table 5. Descriptive statistics of project score at time 1.

	Project-T1 Score				
	N	Min.	Max.	*Mean*	*SD*
Boys	33	4.0	20.0	11.8	4.0
Girls	32	6.0	20.0	12.1	3.2

Table 6. Descriptive statistics of project score at time 2.

	Project-T2 Score				
	N	Min.	Max.	*Mean*	*SD*
Boys	33	5.0	29.0	19.6	5.9
Girls	31	10.0	30.0	20.7	5.0

Table 7. Descriptive statistics of project score at time 3.

	Project-T3 Score				
	N	Min.	Max.	*Mean*	*SD*
Boys	35	11.0	34.0	23.2	5.5
Girls	31	17.0	33.0	25.5	4.1

were employed to assess the normality assumptions among girls and boys for post-CSA scores and ScratchJr Projects at all three time points. The results indicated that the normality assumptions were not met for post-CSA scores and ScratchJr Projects at time 1. However, the normality assumptions were satisfied for the ScratchJr Project scores at time 2 and time 3. Furthermore, Levene's test of homogeneity of variance indicated that boys and girls exhibited comparable variances in ScratchJr Project scores at time 2 and time 3.

Consequently, independent sample t-tests were conducted to examine gender differences in ScratchJr Project scores at time 2 and time 3, as the normality and homogeneity assumptions were met in these cases. On the other hand, due to the violation of normality assumptions, the Mann-Whitney U test was employed to assess gender differences in post-CSA scores and ScratchJr Project scores at time 1.

The Mann-Whitney U test results indicated that boys and girls did not differ significantly in post-CSA scores (Mann-Whitney $U = 755$, $p = 0.2$) and there were no significant gender differences in ScratchJr Project scores at time 1 (Mann-Whitney $U = 540$, $p = 0.9$). Similarly, the independent sample t-tests revealed no significant gender differences in ScratchJr Project scores at time 2 ($t(62) = 0.80$, $p = 0.43$) and Project scores at time 3 ($t(64) = 1.85$, $p = 0.06$).

As a demonstration of students' ScratchJr Projects, Figure 6 presents one of the students' ScratchJr Project artifacts at time 3 close to the end of the curriculum. The

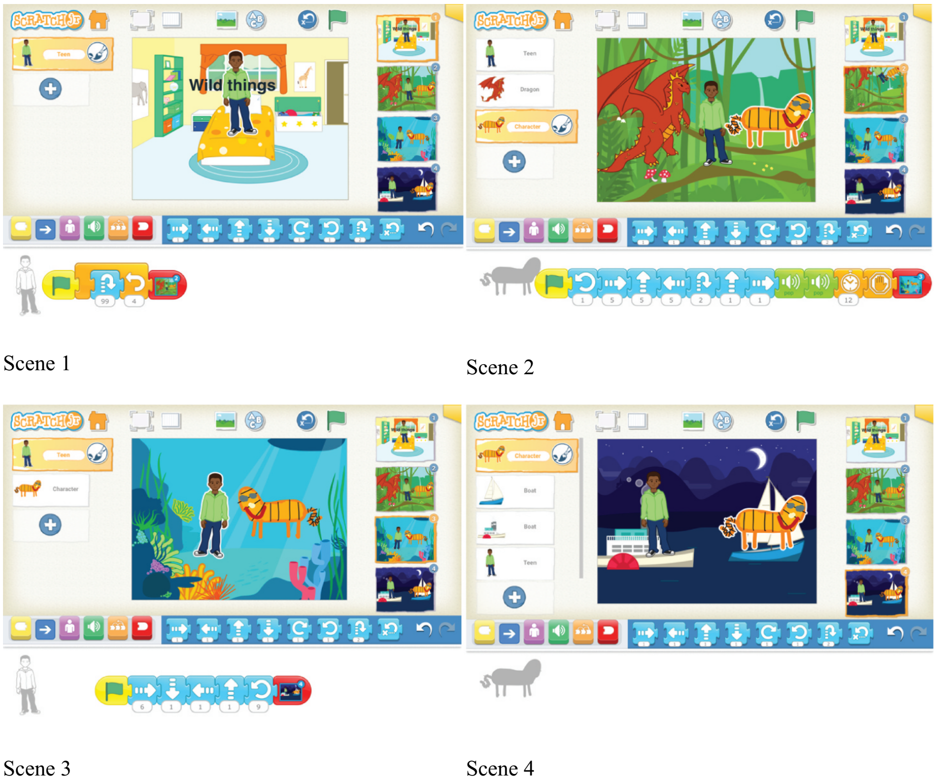

Figure 6. Example Student ScratchJr Projects.

student created four scenes in this project and used a variety of coding blocks to program characters in different scenes.

In summary, in this study, both boys and girls showed a significant increase in their ability to program with ScratchJr. Boys and girls did not differ in their ability of programming as measured by CSA and ScratchJr Projects. While the concept of gender appropriateness can be influenced by many factors such as personal enjoyment, general observation, behaviors of surrounding people (Sullivan, 2016), the results support the finding of Sullivan and Bers (2013) that introducing STEM concepts at a very early age and providing opportunities for both boys and girls to succeed in traditionally masculine areas such as robotics and programming.

Qualitative phase findings

As the quantitative results showed that students improved significantly on their coding performance after CAL-ScratchJr curriculum implementation, it is interesting to explore the CAL-ScratchJr curriculum attributes that might have contributed to the effect, according to teacher's perceptions. After examining the six teachers' interview transcripts, we found the following two themes.

Theme one: student's excitement and engagement

Lessons in the CAL-ScratchJr are organized in terms of four main frameworks including Coding as A Playground, Coding as Another Language, Coding as A Bridge, and Coding as A Palette of Virtues, thus they provide opportunities for students to deeply engage in creating ScratchJr projects in a playful environment, help students internalize the design process and the need of iteration in coding, highlight strengths of students, and help students experience success via the creation of open-ended ScratchJr projects (Bers, 2021). As one teacher commented about the CAL-ScratchJr curriculum, *"So it helped highlights strengths for everyone, really ... everybody blossomed with this"*. (S02T01). Another teacher also shared how students were engaged in the curriculum activities: *"kids get excited about recreating a story, a lot of them got real excited about that"*. (S02T03). One teacher shared an example of how the CAL-ScratchJr curriculum impacted a girl.

> *I have one little girl, who — we had a career day, like you had to dress up what you want to be — and she dressed up like a coder. And I don't think that would have happened without Scratch [ScratchJr], and it just melts my heart.* (S01T02)

Another teacher specifically gave an example of a student who had struggled in some other areas but really engaged and succeeded in the CAL-ScratchJr activities.

> *I have a child who struggles with writing and struggles in some other areas. And I was surprised that he would follow, you know, his coding was cool, it made sense. I was like "Okay, well I didn't expect that". ... So, some kids really blossomed when they might struggle in some other areas, but they were able to do the same concepts like creating a background or setting and characters and stuff, but in a different way.* (S02T01)

These findings in the qualitative phase are consistent with the quantitative results that students showed significant improvement in their coding performance; boys and girls showed comparable coding performance after the CAL-ScratchJr curriculum implementation. The literature presented at the beginning of the paper also indicated that to reduce gender disparity in computer science and programming, the focus should be on strategies to increase girls' interest in programming (Bruckman et al., 2002; Master et al., 2021). Sullivan (2016) also reported that personal enjoyment is one of the factors that help children develop their perception of gender appropriateness of technologies. From these six teachers' comments, CAL-ScratchJr really engaged all students and provided opportunities for all students to succeed, which, according to the literature, is one of the crucial aspects for the success of both boys and girls and reduces gender-interest stereotypes.

Theme two: student's agency

The CAL-ScratchJr curriculum is designed so teachers can create a coding playground in their classrooms (Bers, 2020a, 2020b; Bers, 2012). That is, engaging children in a computer learning experience via open-ended exploration, creation of personally meaningful projects, imagination, problem-solving, conflict resolution, and collaboration just like playing on a playground. In the coding playground, children have agency and autonomy and have opportunities to create their own personally meaningful projects. This reflects the constructionist nature of the approach (Papert, 1980). One of the teacher's comments after implementing the CAL-ScratchJr curriculum reflected such a constructionist approach:

> *I feel like our learners are learning a lot, and I love the openness of ScratchJr that it's not "This is how you get to your point" — you're building the project, you're showing me how this character can disappear and reappear, you're doing it.* (S01T01)

This teacher was referring to ScratchJr time in the CAL curriculum, a period in each lesson in which students program their character Ada Lovelace (from the book they have read) growing up by using Hide/Show, Grow/Shrink blocks in ScratchJr. Throughout the curriculum, students were engaged in the process of preparing for project creation. By the time they had reached Lesson 8, they had honed their skills enough to create their own Ada in ScratchJr, drawing inspiration from a non-fiction book that chronicled the story of a pioneering woman in the field of computer science. Later, in Lesson 19, students were presented with a new challenge: to create a comprehensive 3-page project based on the classic, "Where the Wild Things Are". The teacher read the story aloud, and students were tasked with recalling the order of events and using the "Go-to-Page" block to structure their project and bring their ideas to life. By the end of the lesson, students had successfully created a project that captured the essence of the story's beginning, middle, and end.

These creative coding opportunities offered by the CAL-ScratchJr curriculum are designed to promote a powerful sense of agency for students. As young learners become creative producers, they are encouraged to take ownership of their work, resulting in a greater sense of autonomy and self-direction. This, in turn, helps to foster a strong sense of competence and mastery, which motivates students to engage more deeply in content creation. By creating a positive cycle of motivation, students are empowered to explore their creativity and build their coding skills with confidence. As evidence of this, two teachers' comments reflected that the curriculum had a noticeable impact on promoting a sense of competency among their students.

> *It's a great program because it's not just coding. The kids, like, get that . . . when they can create their character, when they can create their scene, they have more ownership in it. So, I love that part about it. My students may not all be into the coding if they don't understand it, but they're all into creating at this age, so that's a great component to have on there. So, even though they may not totally understand what coding is, they may be creating something else and taking pride in that too, so the different components all coming together in one spot is really neat.* (S01T03)

> *I would say it builds confidence, value, to where they believe in themselves more. Instead of that whole struggle with . . . [unintelligible] and this does not make sense to me, you know. But Scratch [ScratchJr], the coding and understanding that, they got it.* (S02T01)

Such ownership the teachers shared provides students with a strong sense of autonomy, which is a crucial component of motivation for deep explorations. In the process of these rich explorations, students normalized "debugging" and practiced being persistent. Gradually, they internalized that coding is a process that involves constant revisions and multiple iterations. Going through the debugging process promotes perseverance and helps students develop an open mindset about their coding ability. The feedback from teachers highlights the positive impact of the CAL-ScratchJr curriculum on students' perseverance and emotional resilience. As one teacher noted: "*It's helping that emotional, like, toughness*". (S01T02).

Other teachers pointed out the change in students' attitudes in facing challenges after the CAL-ScratchJr curriculum implementation. As one teacher shared, "*watching them work through the program and work through their problems, I really enjoyed watching them build their frustration level a little bit higher, like before they used to get frustrated and just stop*." (S02T02). Similarly, another teacher shared how the learning to code process helped students normalize the process of debugging and problem-solving.

> *They were willing to try things more than once and in different ways. Whereas, even at the beginning of the year, I would have some kids just shut down when they couldn't get something the first time. But I think working through debugging and just even using that language throughout the day, it helped that.* (S01T02)

Another teacher shared how she encouraged one of her students to transfer the debugging skills learned from the CAL-ScratchJr curriculum to other subjects.

> *One of my students who had other challenges, like other STEM challenges, she breaks down crying because her first idea didn't work. So, like, I've brought it back to Scratch [ScratchJr], which she loves. I was like, "Well, sometimes our codes don't work, and then we have to try again and test it and improve it, now it's time to go through that whole process". She was like, "Oh yeah, right", so then she starts over ...* (S01T02)

The CAL-ScratchJr curriculum was designed to support the formation of social relationships (Bers, 2021). In turn, social relationships engaged all children in working on their coding projects. One of the teachers commented that she really enjoyed the process of how such social relationships were developed through collaboration.

> *Watching the students debug or working with each other, if one thing wasn't working for someone or if a student discovered something new, like how to create on a character and make a shape or draw, watching them collaborate* (S01T03)

The interviews with teachers enhanced our understanding of specific features that may have contributed to the success of the CAL-ScratchJr curriculum. As described above, two major themes emerged from the teacher interviews: students were engaged and excited and students developed a sense of agency and autonomy by having the opportunities to engage, experience success, practice debugging, and collaborate with peers in exploring the CAL-ScratchJr curriculum. Additionally, Table 8 presents the evidence corresponding to each research question.

Discussion

The embedded mixed methods study presented in this paper indicates that the CAL-ScratchJr curriculum increases both boys' and girls' coding ability equally. Both boys and girls showed significant improvement in their CSA after the curriculum implementation. Boys and girls showed comparable coding performance from their post-CSA and three ScratchJr Project scores. Additionally, the teachers' comments in terms of engagement and excitement from everyone confirmed that the curriculum is engaging for all, boys and girls. This is consistent with findings of previous studies that aim to reduce gender disparity in computer science and programming.

While the quantitative phase examined significant improvement in students' coding performance after the CAL-ScratchJr curriculum, the qualitative results present a richer

Table 8. Summary of results according to each research questions.

Research Questions	Results
Is there a baseline gender difference in students' coding performance, as measured by the validated Coding Stage Assessment (CSA) before the implementation of the curriculum? (QUAN.)	No significant baseline coding proficiency difference is found between gender ● Mann-Whitney $U = 755$, $p = 0.2$
To what extent does participation in the CAL-ScratchJr curriculum affect children's coding performance, as measured by CSA after the intervention? (QUAN.)	Student's coding proficiency is significantly improved for both boys and girls. ● Repeated measure t-test on CSA ○ Boys: $t(36) = 13.92$, $p < 0.001$ ○ Girls: $t(34) = 10.06$, $p < 0.001$
Is there a significant difference in coding performance between boys and girls, as measured by their CSA scores after the intervention, as well as their scores on the three ScratchJr projects during the curriculum intervention? (QUAN.)	No statistical significance is found on coding performance during the curriculum as measured by ScratchJr projects and after the curriculum as measured by CSA. However, there is a borderline effect that girls showed slightly higher ScratchJr project score than boys. ● ScratchJr Project at Time 1: ○ Mann-Whitney $U = 540$, $p = 0.9$ ● ScratchJr Project at Time 2: ○ $t(62) = 0.80$, $p = 0.43$ ● ScratchJr Project at Time 3: ○ $t(64) = 1.85$, $p = 0.06$ ● Post-Curriculum CSA: ○ Mann-Whitney $U = 755$, $p = 0.2$
What specific attributes of the CAL-ScratchJr curriculum may have contributed to these findings? (QUAL.)	Theme one: Student's Excitement and Engagement ○ The curriculum highlighted strengths for every student. ○ Students' excitement about recreating a story. ○ All students blossomed regardless of their academic performance in other subjects Theme two: Student's Agency ○ Students' ownership from creating their own characters and scenes via open-ended projects ○ The curriculum helped: ■ Build confidence ■ Develop perseverance ■ Debug and collaboration

story by revealing the features of the CAL-ScratchJr curriculum that impressed teachers when they were implementing the curriculum. Teachers shared that the curriculum promoted students' confidence, emotional strengths, perseverance, and collaboration by engaging in the coding of open-ended projects, providing opportunities for students to succeed, practicing the process of debugging, and collaborating with peers. All these teacher-revealed features are a reflection of the PTD theory in action, as CAL-ScratchJr is guided by this theory.

The CAL-ScratchJr curriculum has had a positive impact on students, including both boys and girls, regardless of their academic performance in other subjects. This is a testament to the potential of coding to engage and inspire young learners of all backgrounds and skill levels. Several features of the curriculum may have contributed to its success, and these can serve as a reference for future curriculum design.

One of the key features of the CAL-ScratchJr curriculum that may have contributed to its impact is its emphasis on open-ended exploration and creation of personally meaningful projects. By providing a supportive learning environment, the curriculum enables students to explore their creativity and develop their coding skills through creating animated stories in an open-ended manner. For example, Lesson 19 in the curriculum allows children to create their own endings for their books, using the animations they have programmed in ScratchJr. This helps students develop a sense of ownership on their coding projects and sense of autonomy over their learning in the CAL-ScratchJr curriculum.

Another feature of the curriculum that has helped to engage and inspire learners is using the ScratchJr app as an expressive tool. Unlike some common practices of solving pre-defined puzzles or games in early childhood CS curriculum, the CAL-ScratchJr curriculum uses ScratchJr as an expressive tool, in which students are able to modify characters in the paint editor, add their own voices and sounds, and even insert photos of themselves. Every young learner regardless of their performance in other subjects can engage in such an expressive tool easily. The low-floor, high-ceiling interface of ScratchJr allows children to start with simple projects and gradually move on to more complex ones as their skills improve. This helps to boost their self-confidence and encourages them to continue learning and growing.

In addition to these explicit features of the curriculum, there may be hidden aspects that have helped to encourage girls' interest in coding, such as the intentional inclusion of Ada, a pioneer woman in computer science. This approach to coding education is critical to ensuring that all students have the opportunity to thrive and reach their full potential.

Finally, the CAL-ScratchJr curriculum includes powerful ideas that help students reach their potential. For instance, it integrates the design process into its activities, which involve imagining, planning, revising, and sharing. These activities help students develop and normalize the iterative nature of problem-solving. Moreover, the curriculum emphasizes the importance of debugging to help students analyze, test, and evaluate their coding blocks. Both of these ideas have helped students cultivate perseverance.

Overall, the CAL-ScratchJr curriculum's success for both boys and girls can be attributed to several key features that promote students' sense of agency, build confidence via expressive tools, include underrepresented role models, and incorporate powerful ideas in CS. By taking these features into consideration, future curriculum designers can create more effective and engaging coding programs for learners of all backgrounds and skill levels and counteract gender-interest stereotypes and gender-stereotypes.

Limitations and future research

This study examined children's performance on coding in ScratchJr using the CAL-ScratchJr curriculum to explore the impact of the curriculum as well as whether any gender differences were present. Although boys and girls showed comparable coding performance without any statistical significance, there seems to be a trend that girls have a higher average score generally in different coding tasks. We are curious to know if with a larger sample, the results may become significant. In future studies, we plan to include more participants to examine gender differences in more detail. Kelleher and Pausch (2006) found an increase in girls' interest in learning programming when they were required to create visual stories with specific software. We would also like to investigate further what curriculum features, if any, interest a subgroup more than another, for example, customizing their scenes and design. Additionally, a more detailed qualitative analysis may be done to further investigate the features in the CAL-ScratchJr curriculum.

Another limitation of this research is the lack of a control group for boys' and girls' coding performance, which introduces uncontrolled confounding factors such as development and maturation. It is possible that the observed improvement in coding performance is due to children growing older and acquiring more general knowledge over time. As this study only includes first grade, it is unknown whether comparable gender performance will be maintained in the subsequent grades. A longitudinal study with control groups is necessary to further explore the effect of the curriculum and determine whether comparable performance between gender will be sustained.

Conclusion

Results from this study indicate that introducing computer and programming concepts in early childhood provided opportunities for boys and girls to succeed in historically masculine areas. Both boys and girls showed significant improvement after the CAL-ScratchJr curriculum implementation, and teachers' comments confirmed students' interest and engagement in the program. Additionally, the teachers' interviews revealed that students had successfully developed a sense of agency in exploring the CAL-ScratchJr curriculum. Particularly, the teacher's interview reflected that the curriculum promoted students' confidence, emotional strengths, perseverance, and collaboration by engaging in open-ended coding projects. The CAL-ScratchJr curriculum provided opportunities for both boys and girls, and educators and policymakers should make continued efforts to provide high-quality computer science programs from early childhood to challenge gender-interest stereotypes and promote gender equity.

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