Integrating Elementary Computer Science and Mathematics Instruction: One Size Does Not Fit All

Umar Shehzad, Jody Clarke-Midura, Mimi Recker
Utah State University

Paper presented at the Annual meeting of the American Education Research Association Annual Meeting, Denver, Colorado, U.S.A.
May 2025

Abstract

This paper presents a model, the double integration model, for integrating Computer Science (CS) and mathematics in upper elementary instruction. Fifth-grade students (n=1,037) participated either in the double integrated model (Condition 1; integrated in both CS and Math instruction) or integrated lessons only in CS instruction (Condition 2). After each lesson, students rated their enjoyment, perceived ease, and perceptions of CS-math connections. Multilevel analyses revealed that Condition 1 students reported significantly more positive perceptions and stronger CS-math connections of the lessons than Condition 2 students. Girls in Condition 1 responded more positively than boys on enjoyment and connection items, and outperformed Condition 2 girls across all measures. These findings underscore the double integration model's effectiveness, particularly in enhancing girls' engagement.

OBJECTIVES

There has been a growing recognition of the critical importance of providing equitable access to computing education to all K-12 students (Vakil, 2018). Equitable computing education supports upward social mobility, economic growth, and more diverse technological designs (Ashcraft et al., 2012; De Wit et al., 2023; Pantic & Clarke-Midura, 2019). However, the lack of gender diversity in computer science (CS) has been a persistent concern for decades (Sarabi & Smith, 2023; Verdugo-Castro et al., 2022), with barriers identified at individual, family/peer, school, and societal levels (Alshahrani et al., 2018; Blaney & Stout, 2017; Master et al., 2016; Wang & Degol, 2017).

One emerging and key instructional strategy to support equitable CS education is to integrate CS concepts into disciplinary subjects already taught in schools (Israel & Lash, 2020; Weintrop et al., 2016). This model of integrating CS into regular classroom instruction can provide all students with the opportunity to engage with computing rather than only those enrolled in elective, specialized CS classes. This is particularly important because the disparities between boys' and girls' participation in CS start early, and upper elementary is a critical time to counter stereotypes and barriers that girls face in terms of participating in CS (Master et al., 2021; Sarabi & Smith, 2023; Verdugo-Castro et al., 2022).

Integration offers a solution for how to fit CS into the already overfull school schedule while also supporting learning of core subjects in mutually enhancing ways (Authors, 2023a). Furthermore, this approach allows for the development of curricula and materials that can be tailored to girls' interests, addressing the issue of CS education often aligning more with boys' interests (Peppler & Wohlwend, 2018). Studies suggest that such targeted initiatives can increase girls' participation, self-efficacy, and motivation in CS (Scott et al., 2023; Spieler et al., 2020).

However, integration is difficult to do well, and instructional models for doing so are lacking (Israel & Lash, 2020; Strickland et al., 2021). To address this gap, this paper describes a model in which integrated math and CS lessons are taught during students' regular math instruction as well as during their CS instruction in the computer lab. These "double" integrated lessons taught as part of math instruction use computer science concepts to teach math concepts, while the integrated lessons taught as part of CS instruction use math to highlight CS concepts. This approach not only provides exposure to CS for all students but also allows for modifications in CS instruction and materials that can boost girls' participation (Authors, 2023a; Keune & Peppler, 2019; Sun et al., 2022a, 2022b).

This paper presents findings exploring the impacts of this double integration model from the perspective of the students, including differences between boys' and girls' perceptions. In the study, students either participated in the double integrated lessons as part of both their math and their CS instruction (Condition 1) or only in the integrated lessons as part of their CS instruction (Condition 2). The research questions addressed are:

1. What were students' perceptions of the double integrated math and CS lessons?
2. How did students' perceptions in the double integrated math and CS condition compare to students' who only participated in the integrated lessons as part of their CS instruction?
3. Were there gender differences in perceptions of the lessons between the two instructional conditions?

PERSPECTIVES AND FRAMING

A long line of work has investigated approaches for integrating CS and mathematics instruction (Papert, 1980; Weintrop et al., 2016). Recent reviews on integrating computer science (CS) into elementary school mathematics instruction (Lv et al., 2023; Nordby et al., 2022; Ye et al., 2023) suggest that integration can lower barriers to CS adoption (Fofang et al., 2020) and improve mathematical understanding (Miller, 2019).

Our model for designing integrated CS and mathematics instruction was informed by expansive framing (Engle et al., 2012), an instructional method and theory that explains transfer from a sociocultural perspective. The theory emphasizes mixing contextual elements to enhance transfer and encourages students to take ownership of their learning, tap into prior knowledge, and see themselves as independent problem solvers.

Types of Integration Models

In considering types of CS integration models, Israel et al. (2019) identified three integration levels: no integration, partial integration (e.g., using math to strengthen CS), and full integration (teaching CS and math together). Our double integration model is a *full* integration model; however, it is implemented across two contexts: mathematics instruction *and* CS instruction. In this study, we compare two full integration models: a full (double) integration across two instructional contexts (CS and math) vs integrated in one instructional context (CS).

INSTRUCTIONAL APPROACH: INTEGRATION INTO COMPUTER SCIENCE AND MATHEMATICS

Two integrated units (exponents and fractions) were collaboratively designed with teachers to focus on and highlight connections between CS and mathematics (Authors, 2023b). Following the theory of expansive framing (Engle et al., 2012), the units framed CS concepts within math lessons and math within CS lessons. Design principles for the units included foregrounding alignment with the district's mandated math curriculum (GoMath!) and incorporating instruction into familiar instructional routines (Fisler et al., 2021; Strickland et al., 2021). CS instruction used Scratch and JavaScript blocks within CodeHS, following a use-modify-create approach (Lee et al., 2011).

Exponents and Fractions Instructional Units

The exponents unit teaches multiplication as repeated addition and builds on that to teach exponents as repeated multiplication, highlighting the CS concept of loops. Math lessons explore exponent notation and use Scratch programs to visualize exponential growth (see Figure 1). In the CS lessons, students run and modify Scratch programs to model multiplication (see example in Figure 2) and exponents, emphasizing connections between math operations and programming loops.

The fractions unit uses JavaScript programs to visualize fractions (see Figure 3). In the CS lesson, students program with JavaScript blocks to solve and visualize fraction problems, such as programming a dog to drop tennis balls in specific fractions of a park area (see Figure 4).

METHODS

The study was conducted in a rural Western United States school district, involving 1,037 fifth-grade students (549 girls, 488 boys) from all 17 elementary schools. Random sampling was not feasible due to classroom-based research limitations. Students were assigned to one of two instructional conditions based on the school they were enrolled in.

Procedures

In Condition 1 ($n = 110$), students from four fifth-grade classes in two schools participated in integrated lessons in both their math classroom and computer lab. In Condition 2 ($n = 927$), students from the remaining schools participated in integrated lessons only during CS instruction in the computer lab (see Table 1). In Condition 1, students participated in three integrated math lessons and one integrated CS lesson for each unit (exponents and fractions). In Condition 2, students participated in one integrated CS lesson for each of the two units.

Data Sources

After completing each integrated lesson, students filled out exit ticket surveys containing three items. The items used a 5-point Likert scale and asked students to rate their perceptions of enjoying the lesson, its ease, and seeing connections between CS and math classes (Table 2). Thus, in Condition 1, students completed eight exit ticket surveys across the two units, while students in Condition 2 completed two exit tickets, one for each unit (Table 3).

Validity evidence for exit tickets

Exit tickets generally contain only a few items because they are intended to be minimally disruptive during class time. This brevity creates challenges for establishing validity (Bryk et al., 2015; Penuel et al., 2018). However, exit tickets are considered valid if they generate statistically valid predictions of student outcomes and provide consistent measurements across timepoints. In previous research which used the same dataset as the one used in the present study, we demonstrated consistency through measurement invariance and predictive validity for student affective outcomes, supporting the exit tickets' use as real-time measure of student perceptions (Authors, 2023c).

Data Analysis

We employed multilevel modeling (MLM) for analysis, with repeated measurements nested at level 1 and individual students at level 2. MLM was chosen for its robustness in handling missingness (from student absenteeism or incomplete responses) without requiring imputation or deletion. However, instances with unidentifiable gender were removed during model fitting.

We used the lme4 package in R for MLM analysis. Two separate models were developed: one examining student perceptions in Condition 1, and another comparing differences between the two instructional conditions.

RESULTS

RQ1: Students' perceptions of integrated lessons in Condition 1

Students in Condition 1 showed positive perceptions of the integrated lessons. Means for all exit ticket items were higher than the neutral response across all lessons, indicating positive perceptions of enjoyment, ease, and connections between math and CS (see Figure 5).

Multilevel longitudinal analysis confirmed that student responses were significantly higher than the neutral "not sure" response for all exit ticket items collected during math and CS instruction. (see Figure 6 and Table 4).

RQ2: Comparison of perceptions between Conditions 1 and 2

Comparing exit ticket responses between the two conditions revealed that students in Condition 1 generally had more positive responses than those in Condition 2 (see Figure 7). However, multilevel model analysis showed that not all differences were statistically significant at $p < .05$.

The responses were significantly higher on the "connection" item for Condition 1 students ($\beta = 0.49$, $p < .001$) compared to Condition 2. Differences in the "ease" ($\beta = 0.2$, $p = .078$) and "enjoyment" ($\beta = 0.21$, $p = .069$) items were higher only at the $p < .10$ threshold for Condition 1 students compared to Condition 2.

RQ3: Gender differences in perceptions between instructional conditions

In Condition 1, both boys and girls showed positive perceptions, with means higher than the neutral response (see Figure 8).

Multilevel model results for Condition 1 showed that girls responded significantly more positively than boys on enjoyment and connection items on both computer lab and math class exit tickets. For the ease item, the difference was not significant for exit tickets collected after the math lessons ($\beta = 0.11$, $p = .422$) and was significant for exit tickets collected after the CS lessons ($\beta = 0.29$, $p = .091$) at $p < .10$ threshold (see Table 5 and Figure 9).

Comparing across instructional conditions, girls in Condition 1 responded significantly more positively than girls in Condition 2 across all exit ticket items. For boys, responses didn't differ significantly between conditions for ease and enjoyment items. However, boys in Condition 1 were more likely to respond positively than boys in Condition 2 for the perceived connection item (see Table 6 and Figure 10).

These results suggest that the double integration model in Condition 1 had a more positive impact on girls' perceptions across all measures, while for boys, the only significant difference was in their perceived connections between math and CS.

SIGNIFICANCE

Equitable access to computing education requires meaningful CS participation opportunities for all K-12 students. While integrating CS into core subjects like mathematics is promising, few models exist for elementary-level instruction. This paper presented a double integration model for CS and math, showing positive effects on girls' perceptions of ease, enjoyment and ability to connect these subjects as compared to boys and girls in the single integration model. In summary, our exploration of an integrated math and CS instruction model offers a promising model for broadening girls' participation in CS.

Tables

Table 1 Student participants by unit, condition, gender, and instructional context (*n* = 1,037)

Gender	Exponents unit (Scratch)			Fractions unit (Javascript blocks)			
	Condition 1: Integrated in both math and CS		Condition 2: Integrated only in CS	Condition 1: Integrated in both math and CS		Condition 2: Integrated only in CS	N
	Computer lab	Math class	Computer lab	Computer lab	Math class	Computer lab	
Girls	32	43	380	42	52	327	549
Boys	30	41	334	46	52	272	488

Table 2 Exit ticket items, measured on a 5-point Likert scale

Items	Math lessons	Computer science lessons
Enjoyment	I enjoyed doing the math in today's class.	I enjoyed doing programming in today's class.
Ease (item reverse coded)	Today's math lesson was difficult.	Today's computer lab was difficult.
Connection	Today's class was related to what I do in the computer lab.	Today's class was related to what I do in the math class.

Exit tickets were measured on the following 5-point Likert scale: 0 = Strongly Disagree, 1 = Disagree, 2 = Not sure, 3 = Agree, 4 = Strongly Agree

Table 3 Exit ticket responses from students in the two instructional conditions.

Condition 1: Integrated in Math and CS								Condition 2: Integrated in CS
				# Students across classes 1- 4				
Unit	Subject	Lesson	Total	1	2	3	4	
Exponents	Math	1	79	22	N/A	23	34	--
	Math	2	77	20	N/A	23	34	--
	Math	3	80	22	N/A	26	32	--
	CS	1	62	17	22	23	N/A	714
Fractions	Math	1	91	19	21	24	27	--
	Math	2	92	18	23	20	31	--
	Math	3	96	21	22	21	32	--
	CS	1	88	17	19	27	25	599

N/A: not administered by the teacher (missing across the class)

Table 4 Modelled intercepts for each exit ticket item collected in the math class and computer lab (Condition 1) calculated using the multilevel approach with random effects

Variable	subject	Estimate means	SE
Ease	CS	0.36***	0.1
Ease	Math	0.69***	0.07
enjoyment	CS	0.6***	0.1
enjoyment	Math	0.62***	0.07
connection	CS	0.67***	0.1
connection	Math	0.88***	0.07

*** p <.001

Table 5 Comparisons between boys and girls across subject for each exit ticket item as calculated by the multilevel model (for students in Condition 1)

Variable	**Subject**	**Estimated mean difference**	***SE***	***p***
Ease	cs	0.29.	0.17	.091
Ease	math	0.11	0.14	.422
Enjoyment	cs	0.46**	0.17	.007
Enjoyment	math	0.28*	0.14	.042
Connection	cs	0.48**	0.17	.005
Connection	math	0.31*	0.14	.027

$^{**}p$ < 0.01; * p <. 05; . p < .10

Table 6 Left: Modelled responses by girls in Condition 1 compared to girls in Condition 2, Right: modelled responses by boys in Condition 1 compared to boys in Condition 2 (see also Figure 11)

	Girls			**Boys**		
Variable	estimate	*SE*	p. value	estimate	*SE*	p. value
ease	**0.4****	0.14	.004	0	0.14	.989
enjoyment	**0.41****	0.14	.004	0.01	0.14	.952
connection	**0.69*****	0.14	<.001	**0.29***	0.14	.043

$^{***}p$ < 0.001; $^{**}p$ < 0.01; * p <. 05

Figures

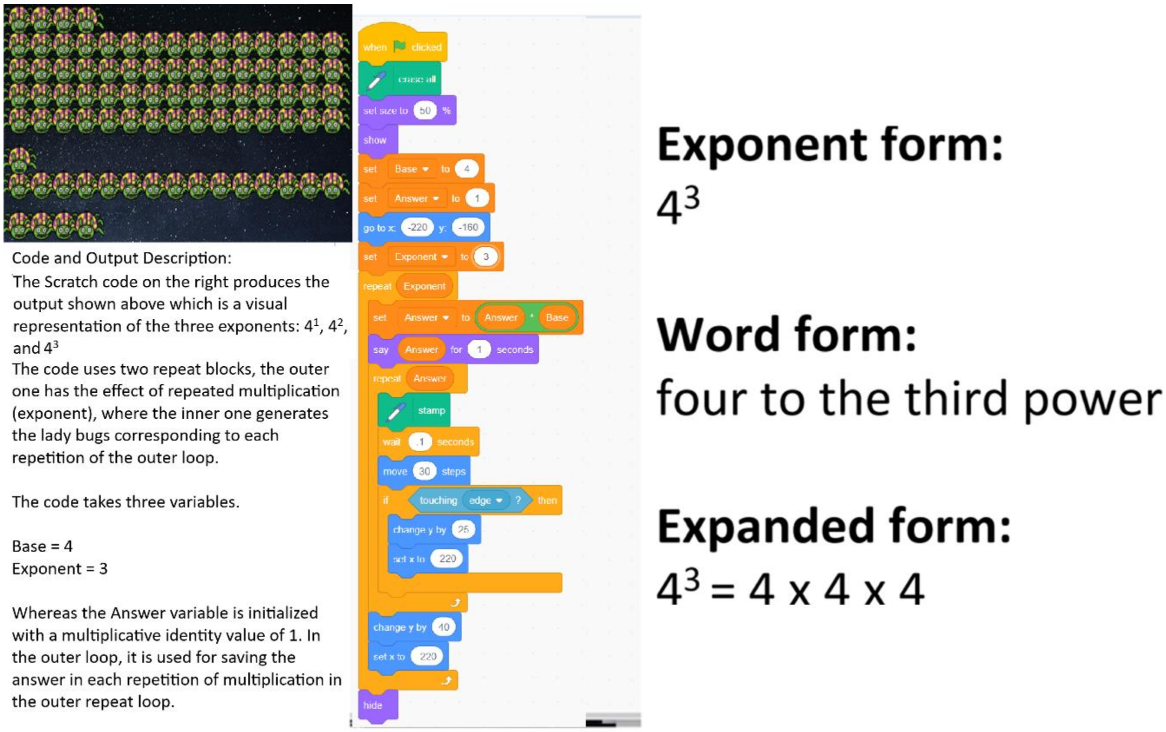

Fig. 1 Math lesson in exponents unit: Using Scratch to visualize exponential growth and connect between different representations of exponents

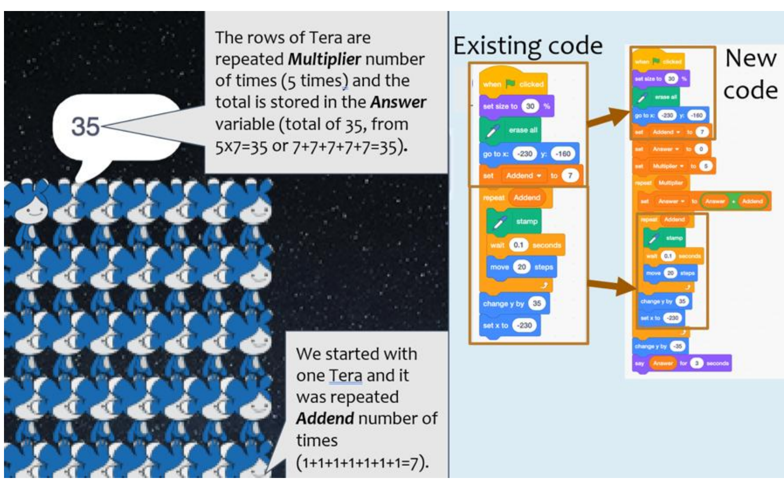

Fig. 2 CS lesson in exponents unit: An example of integrating math content into the Scratch

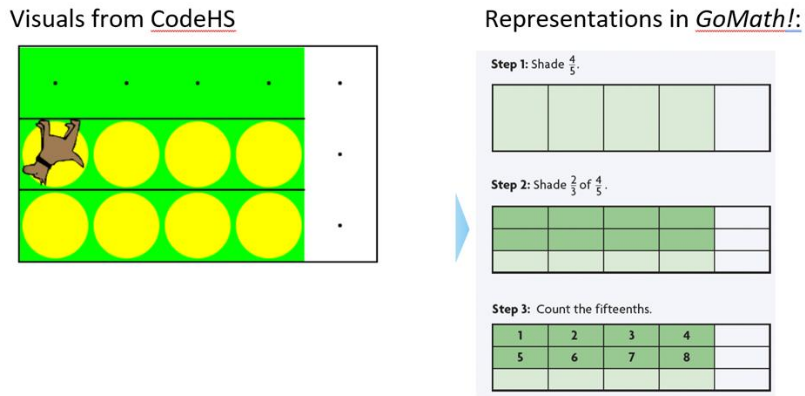

Fig. 3 Math lesson in fractions unit: Running JavaScript programs to visualize and make connections to math representations of fractions

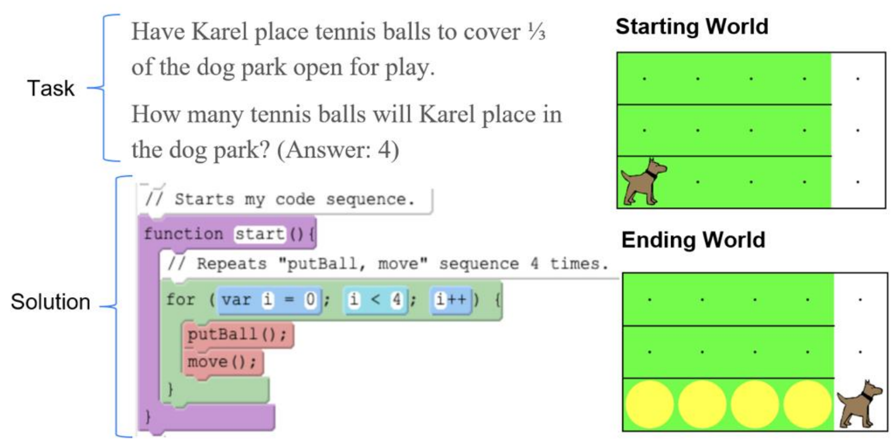

Fig. 4 CS lesson in fractions unit: An example of solving a fractions problem by programming JavaScript blocks to visualize the solution

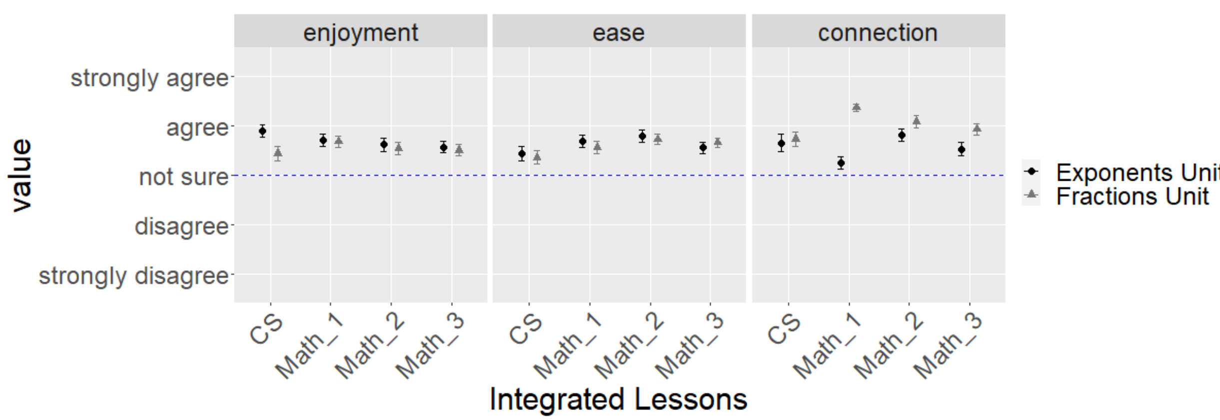

Fig. 5 Means of the student responses in Condition 1 for each exit ticket administration and item (n = 110)

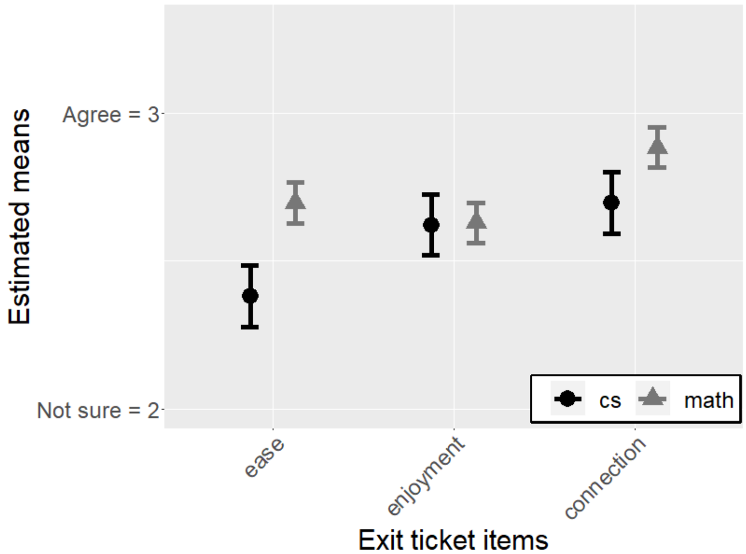

Fig. 6 Modelled responses across CS and math units as calculated by the multilevel model with random effects (for students in Condition 1)

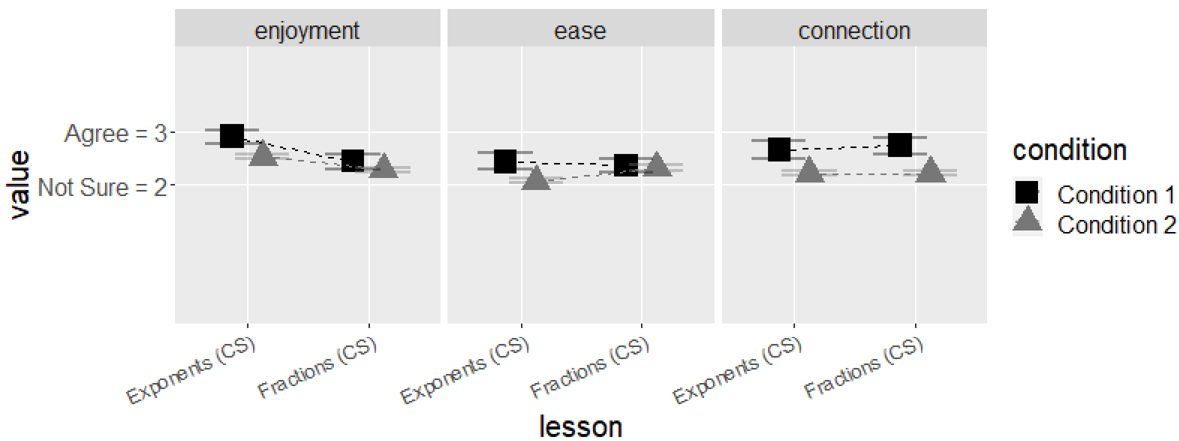

Fig. 7 Means of the student responses on computer lab (CS) exit tickets across conditions

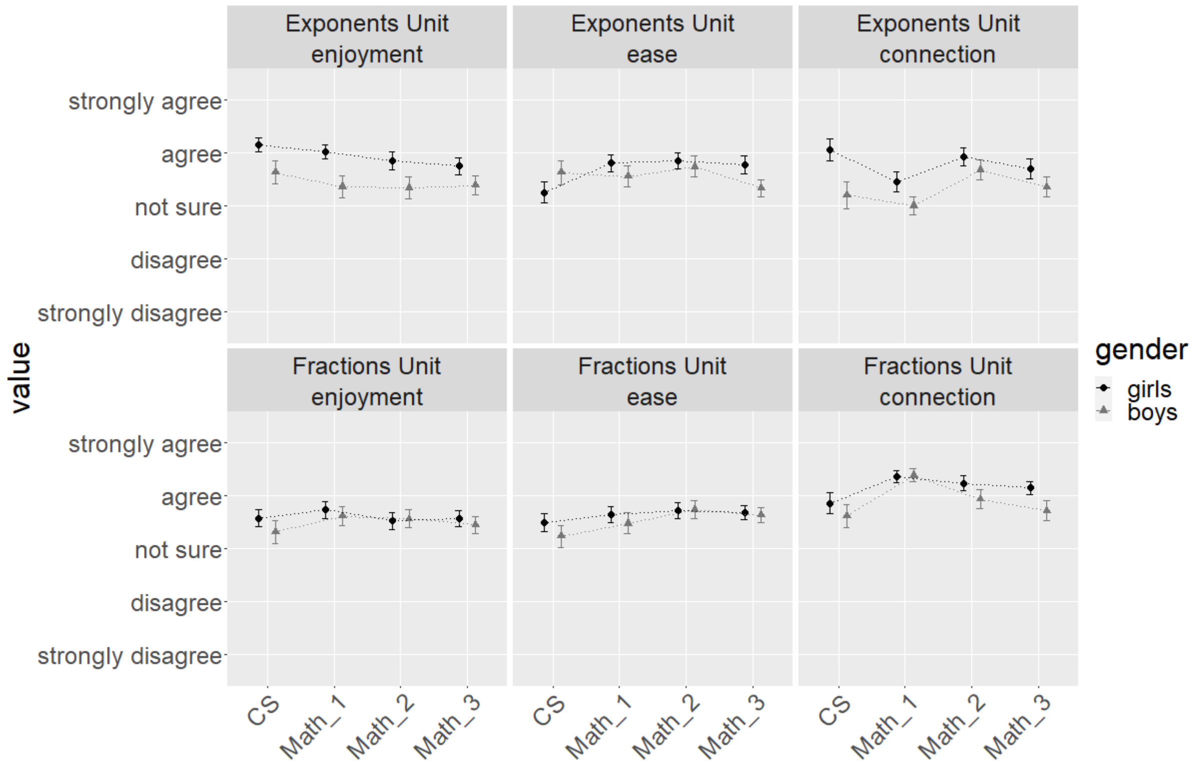

Fig. 8 Means of student responses in Condition 1 for each exit ticket (Girls = 57, Boys = 55)

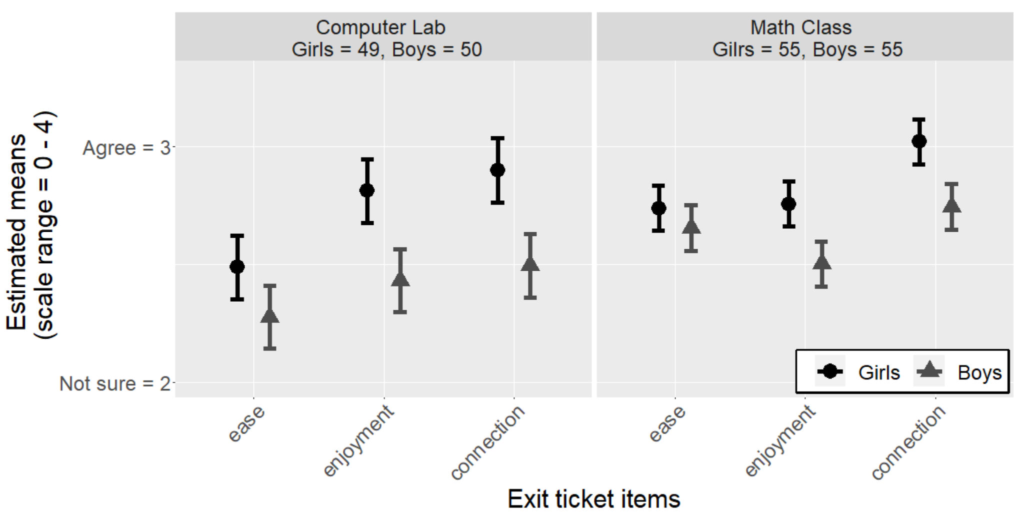

Fig. 9 Modelled responses by gender across CS and math units as calculated by the multilevel model with random effects (for students in Condition 1)

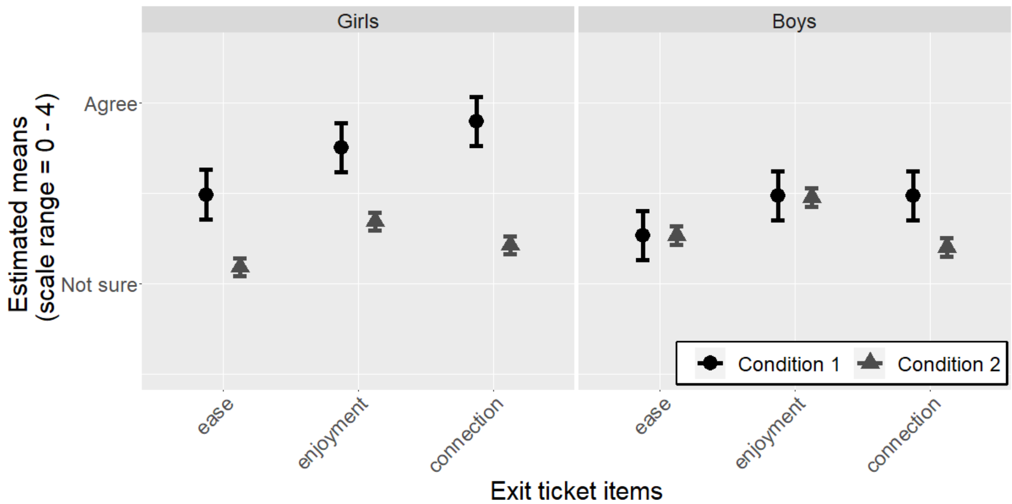

Fig. 10 Modelled responses by boys and girls compared across instructional conditions

REFERENCES

Alshahrani, A., Ross, I., & Wood, M. I. (2018). Using social cognitive career theory to understand why students choose to study computer science. *Proceedings of the 2018 ACM Conference on International Computing Education Research*, 205–214. https://doi.org/10.1145/3230977.3230994

Ashcraft, C., Eger, E., & Friend, M. (2012). Girls in IT: The facts. *National Center for Women & IT. Boulder, CO*.

Blaney, J. M., & Stout, J. G. (2017). Examining the relationship between introductory computing course experiences, self-efficacy, and belonging among first-generation college women. *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 69–74. https://doi.org/10.1145/3017680.3017751

Bryk, A. S., Gomez, L. M., Grunow, A., & LeMahieu, P. G. (2015). *Learning to improve: How America's schools can get better at getting better*. Cambridge, MA: Harvard Education Press.

De Wit, S., Hermans, F., Specht, M., & Aivaloglou, E. (2023). Children's Interest in a CS Career: Exploring Age, Gender, Computer Interests, Programming Experience and Stereotypes. *Proceedings of the 2023 ACM Conference on International Computing Education Research-Volume 1*, 245–255. https://doi.org/10.1145/3568813.3600131

Engle, R. A., Lam, D. P., Meyer, X. S., & Nix, S. E. (2012). How does expansive framing promote transfer? Several proposed explanations and a research agenda for investigating them. *Educational Psychologist*, *47*(3), 215–231. https://doi.org/10.1080/00461520.2012.695678

Fisler, K., Schanzer, E., Weimar, S., Fetter, A., Renninger, K. A., Krishnamurthi, S., Politz, J. G., Lerner, B., Poole, J., & Koerner, C. (2021). Evolving a K-12 curriculum for integrating computer science into mathematics. *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, 59–65. https://doi.org/10.1145/3408877.3432546

Fofang, J., Weintrop, D., Walton, M., Elby, A., & Walkoe, J. (2020). Mutually Supportive Mathematics and Computational Thinking in a Fourth-Grade Classroom. *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS) 2020*, *3*, 1389–1396. https://doi.dx.org/10.22318/icls2020.1389

Israel, M., Hafeez, S., Schanzer, E., Dovi, R., Koslow, E., & Lash, T. (2019). Panel: Making K-12 CS Education Accessibility a Norm, not an Exception. *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, 1232–1233. https://doi.org/10.1145/3287324.3287340

Israel, M., & Lash, T. (2020). From classroom lessons to exploratory learning progressions: Mathematics+ computational thinking. *Interactive Learning Environments*, *28*(3), 362–382. https://doi.org/10.1080/10494820.2019.1674879

Keune, A., & Peppler, K. (2019). Materials-to-develop-with: The making of a makerspace. *British Journal of Educational Technology*, *50*(1), 280–293. https://doi.org/10.1111/bjet.12702

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., Malyn-Smith, J., & Werner, L. (2011). Computational thinking for youth in practice. *ACM Inroads*, *2*(1), 32–37. https://doi.org/10.1145/1929887.1929902

Lv, L., Zhong, B., & Liu, X. (2023). A literature review on the empirical studies of the integration of mathematics and computational thinking. *Education and Information Technologies*, *28*(7), 8171–8193. https://doi.org/10.1007/s10639-022-11518-2

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology*, *108*(3), 424. https://doi.org/10.1037/edu0000061

Master, A., Meltzoff, A. N., & Cheryan, S. (2021). Gender stereotypes about interests start early and cause gender disparities in computer science and engineering. *Proceedings of the National Academy of Sciences*, *118*(48), e2100030118. https://doi.org/10.1073/pnas.2100030118

Miller, J. (2019). STEM education in the primary years to support mathematical thinking: Using coding to identify mathematical structures and patterns. *ZDM – Mathematics Education*, *51*(6), 915–927. https://doi.org/10.1007/s11858-019-01096-y

Nordby, S. K., Bjerke, A. H., & Mifsud, L. (2022). Computational thinking in the primary mathematics classroom: A systematic review. *Digital Experiences in Mathematics Education*, *8*(1), 27–49. https://doi.org/10.1007/s40751-022-00102-5

Pantic, K., & Clarke-Midura, J. (2019). Factors that influence retention of women in the computer science major: A systematic literature review. *Journal of Women and Minorities in Science and Engineering*, *25*(2). https://doi.org/10.1615/JWomenMinorScienEng.2019024384

Papert, S. A. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic books.

Penuel, W. R., Van Horne, K., Jacobs, J., & Turner, M. (2018). *Developing a validity argument for practical measures of student experience in project-based science classrooms*. Annual Meeting of the American Educational Research Association, New York, NY.

Peppler, K., & Wohlwend, K. (2018). Theorizing the nexus of STEAM practice. *Arts Education Policy Review*, *119*(2), 88–99. https://doi.org/10.1080/10632913.2017.1316331

Sarabi, Y., & Smith, M. (2023). Gender diversity and publication activity—An analysis of STEM in the UK. *Research Evaluation*, *32*(2), 321–331. https://doi.org/10.1093/reseval/rvad008

Scott, D., Zou, A., Jacob, S. R., Richardson, D., & Warschauer, M. (2023). Comparing Boys' and Girls' Attitudes Toward Computer Science. *Journal of Computer Science Integration*. https://doi.org/10.26716/jcsi.2023.2.22.37

Spieler, B., Oates-Indruchovà, L., & Slany, W. (2020). Female students in computer science education: Understanding stereotypes, negative impacts, and positive motivation. *Journal of Women and Minorities in Science and Engineering*, *26*(5). https://doi.org/10.1615/JWomenMinorScienEng.2020028567

Strickland, C., Rich, K. M., Eatinger, D., Lash, T., Isaacs, A., Israel, M., & Franklin, D. (2021). Action Fractions: The design and pilot of an integrated math+ CS elementary curriculum based on learning trajectories. *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, 1149–1155. https://doi.org/10.1145/3408877.3432483

Sun, L., Hu, L., & Zhou, D. (2022a). Programming attitudes predict computational thinking: Analysis of differences in gender and programming experience. *Computers & Education*, *181*, 104457. https://doi.org/10.1016/j.compedu.2022.104457

Sun, L., Hu, L., & Zhou, D. (2022b). Single or Combined? A Study on Programming to Promote Junior High School Students' Computational Thinking Skills. *Journal of Educational Computing Research*, *60*(2), 283–321. https://doi.org/10.1177/07356331211035182

Vakil, S. (2018). Ethics, identity, and political vision: Toward a justice-centered approach to equity in computer science education. *Harvard Educational Review*, *88*(1), 26–52. https://doi.org/10.17763/1943-5045-88.1.26

Verdugo-Castro, S., García-Holgado, A., & Sánchez-Gómez, M. C. (2022). The gender gap in higher STEM studies: A systematic literature review. *Heliyon*, *8*(8), e10300. https://doi.org/10.1016/j.heliyon.2022.e10300

Wang, M.-T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review*, *29*, 119–140. https://doi.org/10.1007/s10648-015-9355-x

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, *25*, 127–147. https://doi.org/10.1007/s10956-015-9581-5

Ye, H., Liang, B., Ng, O.-L., & Chai, C. S. (2023). Integration of computational thinking in K-12 mathematics education: A systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education*, *10*(1), 3. https://doi.org/10.1186/s40594-023-00396-w