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Cover Page Footnote

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Ideas at Work

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California 4-H Computer Science Education Pathway

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Abstract. Young people need digital competency and confidence to effectively harness computing power to solve problems and design solutions; a core component is improving young people's computational thinking. Unfortunately, access to computer science education is lacking for all youth, and in particular for youth who live in lower-income households, who are Black or Latino, or live in rural areas. With funding from Google, through the National 4-H Council, California 4-H embarked on a three-year project to build the capacity of 4-H professionals, volunteers, and teenagers to facilitate computer science education with youth. Our programming was effective as assessed with survey methodology. We offer recommendations to Extension professionals in replicating computer science education.

INTRODUCTION

Young people need digital competency and confidence to effectively harness computing power to solve problems and design solutions. Computer science (CS) skills are highly sought after in the job market; thus, helping youth improve their proficiency is important in career preparation (Gallup & Amazon, 2021). Additionally, all youth need computational thinking abilities, even those who do not plan to go into the high-tech workforce. Unfortunately, opportunities for youth to participate in computer science education is limited, particularly for youth in lower-income households, who are Black or Latino, or who live in rural areas (Gallup & Amazon, 2021). Computer science education is strongly related to interest and motivation in pursuing CS in college or as a career. There is a role for Extension in providing computer science education.

A core component of computer science education is computational thinking, the thought processes used to formulate problems in a format that can be solved by a combination of humans and computers (like logical thinking and problem solving). Core computational thinking concepts include decomposition (breaking problems into smaller parts), abstraction (finding patterns and generalizing solutions), algorithm design (including efficiency), and debugging (Shute et al., 2017). Computational thinking is a scientific and engineering practice in the Next Generation Science Standards (NGSS Lead States, 2013) and are recommended for 4-H science, technology, engineering, and mathematics (STEM) programming (Worker, 2013). Helping youth develop computational thinking allows them to become more efficient with technologies (in all fields, not just software engineering), enhance their creativity and innovation, shift their identity to seeing themselves as someone who uses computers and/or becomes a computer scientist, and improve their aspirations to pursue a STEM career (National Research Council, 2010).

CALIFORNIA 4-H COMPUTER SCIENCE PATHWAY

Funded by Google, through the National 4-H Council, California 4-H embarked on a three-year project (2019–2021) to build the capacity of 4-H professionals, volunteers, and teenagers to facilitate computer science education for youth. Our focus was to improve young people's computational thinking and attitudes towards computer science. We emphasized implementing programming to expand the reach of 4-H programming in communities not currently served by 4-H programs or in the computer science field (i.e., Black and Latina girls).

We recognized that with diversity in California's communities, their needs, capacities, and interests, there needed to be flexibility for 4-H professionals to engage their clientele. Extension 4-H professionals implemented CS education by (1) preparing educators (4-H professionals, 4-H volunteers, afterschool staff, or teenagers-as-teachers) to deliver activities in afterschool education settings; and/or (2) short-term introductory CS activities at 4-H events, community festivals, or other venues. By the end of the initiative, we provided computer science learning to over 4,500 youth with the help of 100 volunteers and 50 teens in 17 California counties.

4-H COMPUTER SCIENCE PATHWAY EVALUATION

We selected three programs from two counties to assess the effectiveness of the California 4-H Computer Science Pathway. The remaining counties engaged a smaller number of participants or neglected to collect evaluation data. Our research purpose was to assess and compare learning outcomes from three program models.

PROGRAM SITES AND YOUTH PARTICIPANTS

SANTA CLARA COUNTY: TEENAGERS-AS-TEACHERS PROGRAM MODEL

The third author partnered with a bilingual (Spanish) charter K–12 school in San Jose to train thirty-four 8–11th grade Latinx youth on computational thinking skills for them to be able to teach younger youth. Lessons were facilitated bilingually (in Spanish) using unplugged activities (experiential, group-based activities not requiring computers, adapted from Code.org) and plugged lessons (requiring a computer, using Google's "CS First" platform). For most teenagers, this was their first time learning computational thinking as well as acting as an educator (involving public speaking, group management, and leadership skills). Teenagers were trained using empirically based teenagers-as-teachers essential elements (Lee & Murdock, 2001) using culturally relevant pedagogy (Gay, 2010; Moncloa & Rodriguez, 2022).

Long-Term Programming. Eighth graders taught 4–5th graders, while 9–11th graders taught 6–8th graders. Lessons took place on a weekly basis throughout the school year. Teen members mentored newcomers who joined the group. High school youth who served as teen teachers were new immigrants from Mexico and Central America and many were inexperienced in computer use, let alone coding. To build their confidence to teach, they learned two unplugged activities per group of four and taught the same activities to younger children. At the end of the first quarter, they asked to learn a variety of activities to teach children. See Table 1. In early 2020, community outreach events were canceled, and most schools and after-school programs could not continue with the partnership due to the COVID-19 pandemic since they were experiencing many difficulties engaging children, or their sites were closed.

Short-Term Programming. A different group of five diverse teen teachers in grades 8th-11th facilitated short-term unplugged and plugged activities at community fairs, cultural events, Hour of Code gatherings, and at 4-H conferences for youth from kindergarten through 8th grade. Teen teachers were first generation U.S. born children with ethnic backgrounds from India, Hong Kong, and Mexico. Teens engaged with a diverse population of 303 children in activities that were ten minutes to an hour long in duration. These teens met on a weekly basis using Google hangouts, an online communication service that allows participants to initiate and participate using text, voice, or video chats in a group setting. for updates and next steps under the mentorship of a 4-H volunteer (who was also a Google software engineer) and a 4-H professional. See Table 1. During the COVID pandemic, teen teachers offered activities at virtual 4-H conferences and summer camps.

MARIN COUNTY: AFTERSCHOOL EDUCATION PROGRAM MODEL (LONG-TERM PROGRAMMING)

The first author partnered with a multiple-site afterschool program to secure funding from a California Department of Education "Kids Code" grant. Funding was used to hire two educators and purchase supplies (Chromebooks, Sphero robots). Extension professionals planned a curriculum sequence of 30, hour-long activities with unplugged activities (including lessons from code.org), plugged lessons (with MIT's Scratch and CS First), and programmable robotics (using Sphero); provided professional development to afterschool educators; and administered youth evaluation surveys (see Worker, 2019). The two afterschool educators implemented lessons once per week for 70, 4th and 5th grade youth during the 2019–2020 school year (see Table 1). The program ended early, in March 2020, when the COVID-19 pandemic forced afterschool programs to meet virtually.

Table 1. Demographics Information for Youth Participants

	Santa Clara County: Teenagers-as-Teachers Program Model			Marin County: After-School Education Program Model
	Youth (K–8th grade) Short-Term	Youth (4–8th grade) Long-Term	Teens (8–11th grade)	Youth (4–5th grade) Long-Term
	N=303	N=115	N=39	N=71
Gender				
Female	57%	44%	41%	44%
Male	38%	44%	56%	41%
Non-Binary, Other, Preferred Not to Say, or Not reported	5%	12%	3%	16%
Race & Ethnicity				
Hispanic or Latino	45%	60%	46%	54%
White	17%	2%	10%	0%
Black or African-American	1%	1%	3%	4%
American Indian or Alaska Native	3%	3%	0%	6%
Asian, Native Hawaiian, or Other Pacific Islander	12%	5%	26%	3%
More than one Race	13%	9%	13%	6%
Undetermined, Other, Preferred Not to Say or Not reported	9%	21%	2%	28%
Age	*	**		***
8 or younger	24%	8%	0%	0%
9–10 years	23%	59%	0%	63%
11–13 years	25%	7%	3%	35%
14 or older	24%	10%	97%	0%

*10 youth did not report their age, which is 3% of total respondents (N=303).

**18 youth did not report their age which is 16% of total respondents (N=115).

***1 youth did not report the age, which is 1% of total respondents (N=71).

DATA COLLECTION AND ANALYSES

We utilized cross-sectional survey methodology to assess youth outcomes as an indicator of program effectiveness (see Table 2). Two youth surveys were developed by the 4-H Common Measures evaluation team contracted by the National 4-H Council to meet the specific outcomes of the 4-H Computer Science Pathway. The evaluation team decided to group youth participants by either short-term programming (typically less than an hour) to long-term programming (typically more than 6 hours).

- *Short-Term Programming Survey*: eight items with binary response options (yes or no) and demographic questions (gender, age, and race).
- *Long-Term Programming Survey*: 6-item computer science outcome scale (4 response options from "A lot" to "None"), 2 items about computer science attitudes ("How much do you like computer science?" with 3 response options "A lot" to "Not at all"; and "Would you like a job in computer science?" with 3 response options "Yes' to "No"), and demographic questions (gender, age, and race). We created a computer science outcome composite score variable by calculating the mean of six items measuring computer science skills (Cronbach's alpha = 0.86).
- *Teenagers-as-Teachers Survey:* assess teenager skills in teaching (UC ANR, n.d.) and administered with teenagers who led lessons and contained 8-item retrospective teens-as-teachers scale (4 response options from "Excellent ability" (coded as 4) to "No ability" (coded as 1) (for retrospective pre-test information, see Young & Kallemeyn, 2019).

EVALUATION FINDINGS

OUTCOMES FROM LONG-TERM PROGRAMMING

We compared post-program computer science outcome items between the three groups. Teenagers consistently reported higher means for all items (composite score = 3.6 out of 4), Marin County youth as the second highest (composite score = 3.2 out of 4), and Santa Clara County youth reported the lowest average overall (composite score = 2.8 out of 4). The highest teenager items included working with others to achieve a solution (mean=3.8) and working hard at things that are difficult (mean=3.7); the lowest mean was confidence in the ability to do computer science (3.4). See Table 2.

We calculated an independent samples t-test between Santa Clara County (n=109, compositive score mean=2.8) and Marin County (composite score mean=3.1) and found a statistically significant difference (mean difference=-0.34; *t*-value=-2.64; *p=0.009*; *Cohen's d*=-0.41).

We also compared means between groups on the computer science attitude and career interest items and found that teenagers consistently reported they liked computer science "A lot" (83%) compared to Santa Clara County youth (4–8th graders; 48%) and Marin County (4–5th graders; 48%). See Figure 1.

In comparing means for computer science career interest, we found teenagers also reported a higher interest in CS jobs (86% selecting "Yes" or "Sort of" response options), compared to only 58% of Santa Clara County 4–8th grade youth and 63% of Marin County 4–5th grade youth. See Figure 2.

OUTCOMES FROM SHORT-TERM PROGRAMMING

In Santa Clara County, youth (K–8th grade) that participated in short-term computer science education responded that their participation helped improve their knowledge (78%) and attitude (81%) (see Table 3). Additionally, a majority responded that they do not do other computer science activities during outside of school (57%). Youth responded positively about liking computer science (91%) and the activity they completed (95%).

TEENAGERS' EDUCATOR SKILLS

Teen teachers reported improving their educator skills. We found statistically significant differences between the means of "before program" and "after program" in all items (see Table 4). The items with the largest practical significance (effect sizes calculated using *Cohen's d*; Cohen, 2013) were leading a group discussion, planning programs, public speaking, and teaching others.

Table 2. Post-Program Computer Science Outcome Scores for Three Conditions

CS Outcomes	Santa Clara County Youth (4–8th grade)		Marin County Youth (4–5th grade)		Santa Clara County Teenagers (8–11th grade)	
	N	Mean	N	Mean	N	Mean
1. Confident in your ability to do computer science?	106	2.7	68	3.1	36	3.4
2. Confident in figuring things out that you don't understand?	107	2.8	66	3.2	37	3.6
3. Willing to work harder at things that are difficult?	107	2.9	67	3.1	37	3.7
4. Able to set aside differences to work with others to achieve a common goal or solution?	101	2.9	67	3.1	37	3.8
5. Aware of your strengths and weaknesses when working with others on a problem?	102	2.9	65	3.3	37	3.6
6. Able to deal with open-ended problems?	101	2.9	64	3.2	38	3.5
CS Outcome Composite Score	**109**	**2.8**	**68**	**3.2**	**38**	**3.6**

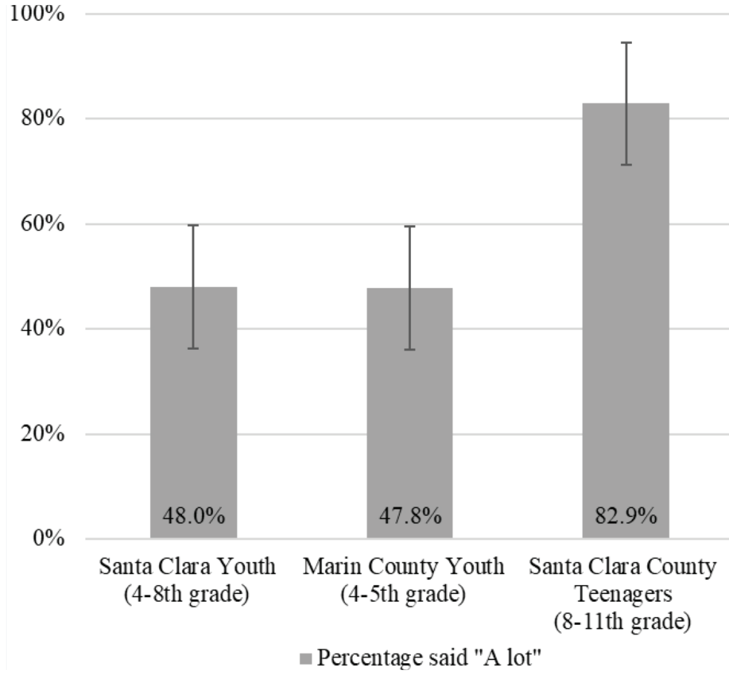

Figure 1. Youth attitudes for computer science: *"How much do you like computer science?"*

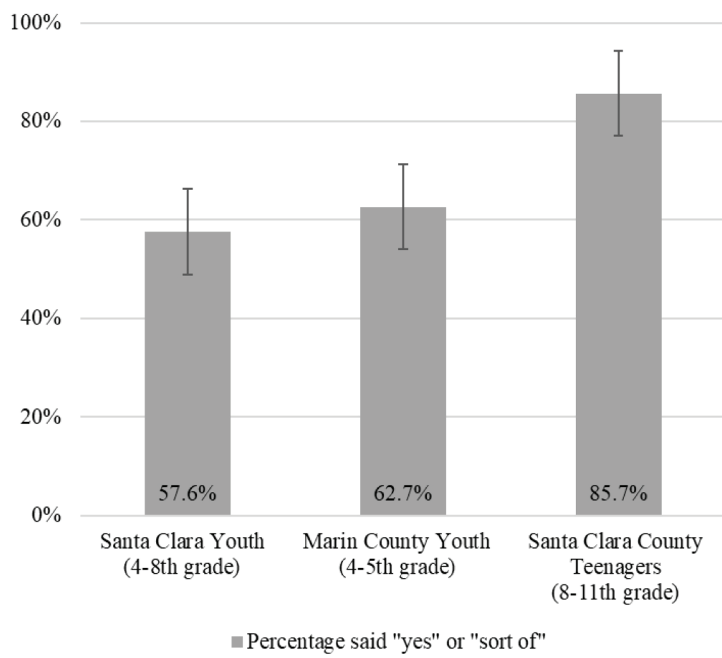

Figure 2. Youth interest in computer science jobs: *"Would you like a job in computer science?"*

Table 3. Santa Clara County Youth (K–8th Grade) Computer Science Education Outcomes for Short-Term Programming

	N	Frequency	
		Yes %	No %
Do you like learning about computer science?	302	91.4	8.6
Do you like the things you got to do in this activity?	302	95.0	5.0
Do you like learning about technology?	298	91.6	8.4
After completing this activity, do you understand computer science better?	292	78.1	21.9
After completing this activity, are you more interested in learning more about computer science?	296	80.7	19.3
Is this the first time you have participated in a hands-on computer science activity?	298	49.3	50.7
Does your school offer computer science?	284	57.7	42.3
Do you do other activities outside of school that are computer science?	289	42.6	57.4

Table 4. Teenagers' Reported Teaching Skills Before and After the Program

	N	Before Program		After Program		Mean Difference	t- score*	Cohen's d**
		Mean	SD	Mean	SD			
I can lead a group discussion	35	2.7	1.0	3.4	0.8	0.6	5.7	0.97
I can work as a team member	35	3.2	0.9	3.6	0.7	0.4	4.02	0.68
I can speak before a group	35	2.9	1.1	3.5	0.8	0.7	4.51	0.76
I can see things objectively	35	2.9	1.1	3.2	.9	0.3	2.95	0.50
I can plan programs	34	2.5	1.1	3.2	0.9	0.7	5.14	0.88
I can teach others	35	2.9	0.9	3.4	0.8	0.4	4.17	0.71
I can share my opinion with adults	35	2.9	1.0	3.3	.8	0.4	3.87	.65
I can organize my time	35	2.7	1.1	3.0	1.0	0.3	3.43	0.58

* *p*-value less than 0.01.
** Cohen (2013)

DISCUSSION

Evaluation results provided positive evidence for the effectiveness of the California 4-H Computer Science Pathway, at least in these two counties, with two program models (teenagers-as-teachers approach and an afterschool education model), albeit with some limitations. Our evaluation methodology did not assess pre-program CS knowledge or attitudes; thus, we must be cautious in attributing improvements to participation in the program.

Regardless of county, 4–8th grade youth reported similar CS attitudes and career interests; although teenagers reported much higher CS attitudes and career interests compared to their younger peers. These differences might be due to teenagers self-selecting into the program (although none had prior CS experience), while 4–8th grade youth in Santa Clara and Marin Counties participated due to their presence in an existing afterschool program (i.e., participation was not voluntary).

Overall, teenagers reported the highest means in the CS outcome items, with Marin County youth reporting the highest for younger youth participants compared to Santa Clara youth. These results have multiple potential explanations. Perhaps having professional educators instead of teenagers implementing the curriculum led to stronger outcomes; or differences in computer science lessons (specific combinations of unplugged, block-based, and programmable robots); or perhaps the duration influenced outcomes as the Marin County CS program provided more CS lessons (total lesson time) than the Santa Clara County sites.

The teenager's evaluation instrument utilized retrospective post-test methodology, and comparisons between the retrospective-pre and post means showed improvements in teenagers' perceptions of their abilities to lead group discussions, plan programs, public speaking, and teaching others. These outcomes align with previous research on how the teenagers-as-teachers program model promotes development for teenage participants (Worker et al., 2019).

RECOMMENDATIONS FOR PROVIDING COMPUTER SCIENCE EDUCATION IN EXTENSION

Both the teens-as-teachers and afterschool education program models worked well in providing computer science education (with an emphasis on computational thinking) to improve young people's computer science learning outcomes. Many youths do not have access to computer science education outside of school (Gallup & Amazon, 2021); therefore, Extension can help fill this gap and provide computer science learning opportunities. Our suggestions for replicating computer science education in 4-H include:

- *Partnerships:* Build and sustain relationships with schools and/or after school programs using an asset-based approach; this will help provide locations for program implementation (Moncloa, Diaz-Carrasco, et al., 2019). This also helps align with the Extension approach of relying on existing relationships, providing education to clientele, and evaluating effectiveness.
- *Youth:* For Latinx immigrant populations, use bilingual materials from Code.org or CS First to support children's dual language learning (National Academies of Sciences, Engineering, and Medicine, 2017).
- *Educators:* Engage culturally diverse educators (teens and/or adults) who have shared lived experiences with participating children (Moncloa, Erbstein, et al., 2019; Moncloa & Rodrigues, 2022). For teachers new to computer science education, develop a learner-centered training to build their competence and confidence to implement curricula lessons with both unplugged and plugged approaches (Kite & Park, 2021). Focus on demystifying notions that computer science and computational thinking is difficult or only people in technology fields can teach these concepts. Computational thinking and computer science are present in our daily lives. (The Bowers Institute, n.d.). Help educators develop their own computational thinking concepts using a variety of unplugged activities. Once educators understand these concepts and can apply them to other contexts (e.g., an algorithm is similar to following a cooking recipe), then introduce plugged activities.
- *Curriculum:* Select age-appropriate curriculum aligned with the learning goals identified for the youth participants. Youth responded positively to curriculum that combined unplugged experiential activities with computer-based activities (using block-based coding), and other CS technologies (like programmable robots, virtual reality, or micro-controllers). See the resource document at https://4h.ucanr.edu/files/280489.pdf

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