4-12-2018

Computer Programming Effects in Elementary: Perceptions and Career Aspirations in STEM

Yune Tran
George Fox University, ytran@georgefox.edu

Computer Programming Effects in Elementary: Perceptions and Career Aspirations in STEM

Yune Tran

Abstract The development of elementary-aged students' STEM and computer science (CS) literacy is critical in this evolving technological landscape, thus, promoting success for college, career, and STEM/CS professional paths. Research has suggested that elementary-aged students need developmentally appropriate STEM integrated opportunities in the classroom; however, little is known about the potential impact of CS programming and how these opportunities engender positive perceptions, foster confidence, and promote perseverance to nurture students' early career aspirations related to STEM/CS. The main purpose of this mixed-method study was to examine elementary-aged students' (N = 132) perceptions of STEM, career choices, and effects from pre- to post-test intervention of CS lessons (N = 183) over a three-month period. Findings included positive and significant changes from students' pre- to post-tests as well as augmented themes from 52 student interviews to represent increased enjoyment of CS lessons, early exposure, and its benefits for learning to future careers.

Keywords Elementary STEM education · Motivation · Computational thinking · Careers

1 Introduction

Innovation is key to America's economy, but the United States still falls behind its coun-terparts in producing enough of its own skilled workers with sufficient computer science (CS), science, technology, engineering, and math (STEM) competencies. Reports from the National Academy of Science (NAS) have called for more skilled STEM professionals in the U.S., a crucial need for the country's economic stability and innovation (NAS 2007, 2010). STEM/CS jobs are expected to grow faster than any other job category; therefore, education plays a critical role in equipping a more qualified, educated, and flexible labor force. These factors have led to numerous press accounts by elected officials at local and national levels to expand STEM and CS education, and most recently, by President Obama in his final State of the Union Address (2016) to include CS for all students. Meanwhile, policy recommendations coupled with new content standards and stronger recruitment ini-tiatives in higher education are raising consciousness in STEM/CS education. Thus, foun-dations, non-profits, corporations, and governmental agencies have infused monetary and human resources to solve the challenge and produce more STEM/CS graduates.

Some attribute the STEM/CS shortage in the U.S. to the overall quality of academic prep-aration of U.S. school children. School test scores in the areas of math and science are con-sidered a strong predictor in the availability pool of STEM talent (Committee on Science, Engineering, and Public Policy 2007). Fourth-grade students from the U.S. ranked eleventh out of 52 countries participating on 2011 TIMSS (Trends in International Mathematics and Science Study) and eighth-grade students ranked ninth out of 45 countries participating. In addition, the U.S. ranked 34th on the 2012 PISA (Program for International Student Assess-ment 2012) test in mathematics, reading, and science. While the U.S. is making progress in the area of mathematics, the PISA test has been shown to better address applications of mathematical reasoning to real-world situations (PISA 2012). These deficient scores have suggested that the U.S. school system delivers a less robust science and math curriculum, exacerbating the shortage of STEM/CS workers for a productive economy.

Given this predicament, the U.S. has invested in improving STEM/CS education with efforts in adopting new K-12 content standards (i.e. Next Generations Science Stand-ards), expanding requirements for more rigorous STEM/CS courses, improving curricu-lum with interdisciplinary learning that infuse CS topics, reducing barriers for students to engage in STEM/CS learning; promoting positive perceptions and attractiveness of STEM/CS careers, and encouraging parental input in students' career trajectories. Research has established that applying CS technology with STEM disciplines advances students' critical thinking and problem solving skills through mathematical models that allowed scientists and engineers to analyze, predict, and reconstruct systems that were previously impossible (NRC 2012). Computing initiatives have been introduced across the country; however, they were decentralized and have focused largely on secondary or tertiary school levels. Fewer initiatives were implemented and researched at the elementary level; therefore, DeJarnette (2012) emphasized the need for elementary STEM/CS initiatives given appropriate early exposure that can promote children's inherent curiosity about how things work (Moomaw, 2012).

2 Literature Review

Establishing the nation's youngest students with a strong foundation in basic computing and computational thinking is vital for propelling STEM/CS education while expanding access into elementary classrooms helps increase the quality and quantity of students in the STEM/CS pipeline. Research has advocated for early education initiatives to alleviate equity issues associated with technology that have persisted for students from marginalized and underserved communities including females, English Learners (ELs), and children identified a intellectually disabled (Andersen 2005; Campbell et al. 2000). With NRC's recommendations (2012) for broadening CS exposure and Jeanette Wing's seminal call (2006) on the importance of computational thinking (CT) skills coupled with current research initiatives for embedding CS technologies as in integral part of education and to improve workforce development (Barr and Stephenson 2011), the field of CS has included CT with existing K-12 content and curriculum (Jona et al. 2014; Israel et al. 2015; Wilensky et al. 2014). Moreover, embedding CT concepts, its tools and practices into interdisciplinary contexts especially in math and science promotes students' understanding of the fields, equips them with foundational STEM knowledge, increases career aspirations in STEM, and creates students who are more productive STEM citizens (Augustine 2005; Weintrop et al. 2016).

2.1 Essential Computational Thinking in the Early Years

Elementary-aged students need exposure to interdisciplinary STEM/CS content to col-laborate, explore, create models, analyze, and draw conclusions. These skills are appli-cable to many areas of students' lives, thus, promoting their development is essential in today's classrooms. Past research has suggested improved cognitive benefits such as problem-solving, mathematics, and reasoning for children who participated in computer programming as compared to children who did not participate in similar learning expe-riences (Clements et al. 2001; Liao and Bright 1991). Other benefits included long-term effects such as increased enjoyment with inquiry-based learning, sustained attention, and self-direction, (Clements 1987). Contemporary programming literature emphasized ongoing support for children to engage in innovative programming environments and languages such as Scratch, Kodu, Etoys, and Lego We-Do since they provide age-appro-priate materials for children to apply core CT concepts such as abstraction, automa-tion, analysis, decomposition, and iterative design (Bers and Horn 2010; Mioduser et al. 2009; Resnick 2006).

Existing benefits indicated that inquiry-based science, numeracy, and literacy activi-ties during preprimary and primary years provide elementary-aged students appropriate learning experiences around STEM/CS topics that shape content knowledge, attitudes, and achievement in science and math (NRC 2012; TIMSS 2011). Recent research suggested the importance of computer programming and robotics integration for children in the early years given the benefits of improving STEM knowledge in the classroom. A study con-ducted by Kazakoff et al. (2013) found that children's sequencing skills improved from pre- to post-test after engaging in a one-week intensive robotics and programming work-shop. The children who participated in that intervention utilized a tangible software called CHERP which allowed them to control a robot's behaviors with a variety of physical/tan-gible and graphical/on-screen movements (Bers 2010; Horn et al. 2011). The learning of computing has improved learners' higher-order thinking skills and algorithmic problem-solving skills as validated by current research (Fessakis et al. 2013; Kafai and Burke 2014) and enriched cognitive benefits for gifted students who utilized these skills to create prod-ucts, games, and digital storybooks (Lee et al. 2011). The support of Wing's (2006) call on foundational computational thinking skills has popularized into research given the intellec-tual benefits and applicability of CT to diverse facets of students' lives. The International Society for Technology in Education (ISTE) (2017) has endorsed the preparation in CT's multi-dimensional structure which involves thinking, attitudes, and behaviors that are criti-cal among twenty-first century learners. Moreover, many scholars have agreed on CT's sig-nificance and that young students have the capacity for tackling various mental challenges even at the earliest years of school (Bers and Horn 2010; Duschl et al. 2007; Harris and Rooks 2010; Magnuson and Palincsar 2005).

2.2 Attitudes, Environment, and Self-Efficacy in STEM/CS Learning

Countless factors have influenced students' perceptions around STEM/CS content. While individual differences play a critical role in learning, students' attitudes, self-concept, and the learning environment can bolster views on the importance of STEM/CS learning. Past research on science education indicated that an individual's attitude or belief about school science was a determining factor on influencing human behavior (Newhouse 1990). Personal opinions formed from life and educational experiences were essential to how these attitudes were manifested. Moreover, researchers have discussed the relationship between learning environments and students' affective behaviors which have altered attitudes positively or negatively as a result of the transmission of science knowledge (Riah and Fraser 1997; Puacharearn and Fisher 2004; Wahyudi and David 2004).

Classroom environments have also influenced strong predictors in students' attitudes and beliefs about science. Edmonson's (1989) study revealed students' views on the nature of science, their definitions of learning, and preferences to studying and learning science. Studies have shown that students' attitudes were positively correlated to classroom environments that adopt constructivist models, (Riah and Fraser 1997; Aldoplhe et al. 2003) whereas, negative emotions were related to traditional methods of science instruction (Oh and Yager 2004). Learning approaches that emphasize rote memorization can create an environment where students have a difficult time connecting new learning to prior knowledge. Instead, students' attitudes improve when they have opportunities for imagination, inquiry, creativity, and objectivity which allow for trial and error through the manipulation of learned material to build understanding and motivation in learning about a subject. Some emerging approaches that support systemic classroom environments have included blended methods that pair face-to-face with technology instruction to support student learning of different topics, (Lou et al. 2012) though, they are often related to reading and math (Barshay 2011; Kuo et al. 2014). The emphasis for using of technology in the classroom was supported as a way to increase student engagement in science (Boyles 2011). Other environmental factors for using technology were associated with time allotment, whole class, small group, individualized learning, and differentiated instruction to meet students' needs. A survey conducted by the Center of Digital Learning (2013) reported that 59% of teachers indicated that students were more motivated to learn within blended environments. Thus, blended learning has increased in implementation across many K-12 classrooms as ways to improve student engagement, motivation, and attitudes about particular content (Horn and Staker 2011).

Research has also suggested that when learners integrate new concepts to existing related concepts, acquisition of meaningful scientific understanding increased (Cavallo 1996; Cavallo et al. 2004). Thus, students' willingness to learn the material or motivation was related to their self-efficacy. Rooted in Bandura's (1993) social cognitive theory, self-efficacy is the ability to judge one's capability to execute the required action for success. For example, individuals reflected and answered questions on whether they were able to fulfill particular tasks in a situation, which were related to their self-efficacy (Pintrinch and Schunk 2002). Mastery experiences; physiological and emotional states, vicarious experiences, and social persuasion are all sources that impact one's self-efficacy. Previous research conducted from Anderman and Young (1994) and Wolters et al. (1996) on 678 and 434 middle-school students, respectively, have explained how mastery experiences provided powerful sources of information to influence self-efficacy in the motivational and learning of science and math content. Findings from both studies revealed that a positive correlation existed between self-efficacy and mastery goal orientations. Thus, the more practice an individual has on a task, the more successful s(he) is at in performing that task, leading to improved self-efficacy. Additional influences on efficacy involve vicarious experiences and social persuasion through the observation of others performing the task or through the impact of peers enacting similar attitudes to change the behavior. In other words, students' positive self-efficacy on STEM/CS related-tasks and skills operate best under environments suited for productive opportunities that connect and build from prior knowledge. These opportunities should involve interaction with teachers and peers to provide continual practice for mastery to boost confidence and strengthen optimistic views about the discipline.

2.3 College and Career Aspirations

A major influence for students entering a STEM major in college has revolved around their formative academic preparation and attitudes about math and science in school (Correll 2001; Tai et al. 2006). Attitudes regarding career aspirations have been linked to studies based on expectancy-value models that measure gender and racial differences in math and science as well as students' self-concept and beliefs on how successful they perceived themselves performing on future tasks (Eccles et al. 1998; Nagy et al. 2006; Wingfield and Eccles 2000). Attitudinal differences were found across gender, racial, and age groups in math and science disciplines; however, positive attitudes were found to influence career aspirations and students' educational success in these subjects (DeWitt et al. 2014; Papa-nastasiou and Papanastasiou 2004; Papanastasiou and Zemblyas 2002; Riegle-Crumb et al. 2010).

Career aspirations have remained elusive as when they begin across children's devel-opmental trajectory. Some theories of career development have suggested that by the end of childhood, adolescents have emerged actively exploring their career aspirations (Hol-land 1985; Trice and McClellan 1993). Other past theories have argued that children's career aspirations begin in early childhood prior to the age of 11 during play explorations (Ginzberg 1952); were heavily influenced by the quality of family experiences, structure, and configuration (Roe 1957); or were identified with positive perceptions from paren-tal occupations (Elkind 1982; Trice and Tillapaugh 1991). The most current theory has proposed that career aspirations were derived from a developmental approach across four stages (Gottfredson 1981). In stage one, 3–5 years-old children recognized that adults have occupational roles. During stage two, 6–8 years-old children recognized that gender roles were associated with various occupations and eliminated those that they perceived were inappropriate for their gender. In stage three, 9–12 years-old children became aware of the social prestige and intelligence level needed for particular occupations, thus, eliminating occupations they perceived as too difficult or with low prestige. A study by Seligman and Weinstock (1991) found that half of a group of 9 and 10 years-old children have already determined their future career based on self-perceptions. At around stage four or 14 years-old, adolescents' aspirations were related to their interests, values, and competencies.

In addition to developmental theories of aspirations, social psychological research has indicated that decisions individuals make regarding their occupations are formative (Bandura et al. 2001). In early childhood, future occupations were influenced by fantasy ideas (Seligman and Weinstock 1991) whereas for older children, imaginative ideas were replaced by concrete ones that become more representative of their future career choices. Research experts have agreed that by adolescent years, individuals have chosen their career paths based on some knowledge base and practical exposure of those fields in their lives (Auger and Blackhurst 2005; Chen 2009; Gottfredson and Lapan 1997; Seligman and Weinstock 1991).

2.4 Parent Influences on Education and Career Development

Research has suggested that parental influence on children's education is a strong predic-tor of academic success (Ing 2014; Tran 2014). Findings were consistent for students from early childhood to high school that indicated a positive relationship with parental prac-tices to students' achievement outcomes on standardized test scores, intrinsic motivation, career aspirations, and participation on advanced high school courses (Ma 2001). Research around career development has suggested the influence of parental recommendations to what their children selected as future jobs (Middleton and Loughead 1993; Splete and Freeman-George 1985). This body of knowledge has argued that parents had a direct and indirect role to the impact of their children's career choices, even more than counselors, friends, community members, and teachers (Trusty 1996; Young et al. 1997). Parents' indirect effects included the influence on children's beliefs, self-concept, and goals when they encouraged their sons or daughters to succeed in school or attend college to pursue careers (Cinamon and Dan 2010). Several scholars have emphasized the role that parents play in influencing mathematics achievement as it related to students' career choices in STEM and persistence in those disciplines (Ing 2014; Hong 2010; Ma 1999). High expec-tations where parents emphasized success in math had a direct impact on students' pursuit of STEM careers (Hong 2010). In short, parents were powerful sources of influence for children's career trajectories. They served as extrinsic motivational agents when they uti-lized strategies to reward students for good grades or high achievement scores (Harackie-wicz et al. 2012). Additionally, through intrinsic methods, when parents promoted optimis-tic perceptions about future jobs, encouraged curiosity, and recognized students' academic achievements in school or beyond, their children were more likely to achieve educational and career success (Gottfried 1990).

Given that the individual choices children make to enter prospective careers varied and were derived from parents or early exposure, it is essential to provide elementary-aged stu-dents with developmentally appropriate STEM/CS opportunities in the classroom to foster growth and career trajectory (Chen 2009). From engaging projects to robust online educa-tion games, these experiences can engender positive perceptions, foster confidence, and promote perseverance to nurture students' early career aspirations related to STEM/CS. Limited research existed about the career aspirations of elementary-aged students within STEM/CS disciplines and even less literature was found on underrepresented economi-cally-disadvantaged students despite increased evidence and attention referencing the need for career development starting in early childhood (Magnuson and Starr 2000; Trice et al. 1995). Therefore, research is needed to contribute to the field by exploring elementary-aged students' attitudes and perceptions about STEM through CS opportunities that lever-age access and knowledge in computational thinking and technological literacy. The main purpose of this study was to examine elementary-aged students' perceptions of STEM and career choices from pre- and post-test intervention of CS lessons. The research ques-tions for this study were: (1) What are elementary-aged students' attitudes about STEM and career aspirations? and (2) What influence does a CS intervention program have on elementary-aged students' attitudes about STEM and career aspirations?

3 Methods, Data Sources, and Analysis

An exploratory mixed-method approach was utilized to combine strengths from quantitative and qualitative procedures (Creswell 2003). Data collection and analysis were completed during the 2015–2016 academic year. Quantitative procedures were used to analyze students' pre- and post-test assessments and surveys whereas qualitative methods were used to analyze students' interviews. Participants recruited for the study included elementary-aged students from thirteen classrooms in five schools from two districts located in Oregon. The two districts were also selected due to the growing numbers of economically-disadvantaged and diverse students in recent years. Selected underrepresented elementary-aged students enrolled from the two districts included those from economically-disadvantaged backgrounds (between 45 and 59%), a growing Latino population (between 17 and 20%); ELs (between 9 and 15%), and special education students (between 6 and 11%) (ODE 2015). Thirteen elementary classrooms were selected by five different principals from the two districts to participate in the CS coding project composed of one lesson each week for a period of 10 weeks during the fall of 2015. Each lesson was approximately 60 min long and delivered by a preservice teacher through a hybrid format composed of interactive hands-on CS concepts followed by online coding puzzles adapted from Course 2 of the elementary framework from code.org (http://code.org) and CSUnplugged (Bell et al. 2011). Preservice teachers crafted weekly lessons and received feedback from education faculty on plans with additional content and pedagogical training of those lessons from a team of university faculty members with background in curriculum, STEM, and CS prior to lesson delivery. To check implementation, preservice teachers kept written reflections of each lesson which were turned into education faculty. Additionally, at least two observations were completed on each classroom throughout the cycle. All lessons were embedded as part of the regular day and were delivered during a content block allowing for interdisciplinary teaching of concepts. Informed consent from students participating in the research was obtained through returned parent permission forms. Elementary students completed a pre- and post-test on computational thinking that was developed by the researcher with consultation from the university's CS department. Constructs of the assessment included 10 written items that measured five different CS concepts with two questions per concept related to sequence, algorithm, looping, debugging, and conditionals. An example of a sequencing test item included: "Put these mixed-up instructions for baking a cake in order using only four steps. Write numbers 1–4 next to those steps." In this task, students analyzed each step of the algorithm drawing on CT practices and perspectives by relying on familiar experiences. Students completed the instrument by hand in class before and after the intervention period. Accommodations in terms of oral administration, extra time, or text translation were provided to students if needed. Assessments were collected and scored for each item (1 correct, 0 incorrect) following each administration. In addition, students completed pre- and post-test surveys based on 44-items on a five-point scale that measured aspirations, beliefs, and goals in STEM; attitudes from parents and peers about STEM; and enjoyment in STEM-related tasks. The researcher developed the survey with adapted questions from a questionnaire used in the ASPIRES project (Archer et al. 2013). The researcher pilot tested both instruments on a group of third-grade students unrelated the research project about 4 months prior to the pre-test collection to ensure appropriate vocabulary and understanding of the constructs. Analysis of the computational assessment included 183 paired samples whereas analysis of the STEM survey included 132 paired samples from pre- to post-test. Computational test questions and STEM survey items are included in Appendix A and B respectively.

Cronbach's alpha was calculated for each survey administration separately and internal consistency indicated similar alpha values in both administrations. Reliability scores were between .73 as the lowest to .84 as the highest based on the four STEM subject groups with an internal consistency reliability score of 0.94 using Cronbach's alpha. Final paired responses included 132 students from pre- and post-surveys. To further triangulate data, 52 semi-structured student interviews with open-ended questions were conducted through random selection of about four students per classroom. At the start of each interview, the researcher initiated conversations about students' enjoyment of various interests (i.e. school-related and extracurricular), tasks, and fun activities to build students' trust, comfort, and confidence in answering questions. The researched posed a series of questions related to learning outcomes of coding lessons and students' perceptions of in and out-of-school related activities. Priming for student answers rarely occurred as the majority of students shared eagerly and reflected positively on their learning experiences given that the topics were relatively new to them. Each student interview lasted between 5 and 10 min with various questions that included: What are things that you enjoy doing?; What do you think about when you hear the words: science, technology, math, engineering?; What job do you want when you grow up?; What are you learning in coding?; How do you feel about these lessons?; Is coding important in school or in your future job? Interviews were completed, transcribed, and coded by the researcher and a student assistant using theme analysis with techniques that searched for word repetitions or key words in context (Strauss 1992); a careful reading of larger blocks of text to compare and contrast (Gla-ser and Strauss 1967), and an intentional search of linguistic terms (i.e. because, so, etc.) that described causal relationships (Strauss and Quinn 1997). A conducted from a mixed-method approach was utiliemployed given the unique blending of benefits from qzingto utilize the beneficial strengths of quantitative and qualitative research paradigms (Creswell 2003; Patton 2002). Results report quantitative measures of the computational assessment and the STEM survey instrument using (STATA) software including various qualitative themes that emerged from students' interviews such as: (a) individual STEM subject perceptions; (b) enjoyment activities related to extracurricular, STEM, and CS concepts; (c) relationship of learned CS concepts to STEM subjects; and (d) benefits of learning CS concepts to future jobs. Themes supported the value of infusing computational thinking

Table 1 Pre- and post-test percentages, correct by item, total score

Assessment construct	Item	Pre	SD	Post	SD	Total	SD	Change
Sequence	1	0.51	0.50	0.74	0.44	0.62	0.49	0.23
Sequence	2	0.45	0.50	0.62	0.49	0.54	0.50	0.17
Algorithm	3	0.61	0.49	0.80	0.40	0.70	0.46	0.19
Algorithm	4	0.28	0.45	0.40	0.49	0.34	0.47	0.11
Loop	5	0.21	0.41	0.39	0.49	0.30	0.46	0.18
Loop	6	0.03	0.18	0.08	0.27	0.05	0.23	0.04
Debug	7	0.09	0.29	0.08	0.27	0.08	0.28	-0.02
Debug	8	0.45	0.50	0.69	0.46	0.57	0.50	0.23
Conditional	9	0.58	0.49	0.70	0.46	0.64	0.48	0.12
Conditional	10	0.11	0.32	0.22	0.42	0.17	0.38	0.11

Note: Overall increase from pre- to post test was significant at $p < .0001$ level

Table 2 Results of elementary students' overall perceptions on pre- and post-test survey

School ID	N	Pre	SD_{pre}	Post	SD_{post}	Total	SD_{tot}	Δ	$Δ/SD_{tot}$
10	37	3.78	.56	4.04	.47	3.91	.53	0.26	0.49
20	11	4.09	.57	4.01	.52	4.05	.53	−0.08	−0.15
30	18	4.19	.70	4.22	.51	4.21	.61	0.03	0.05
40	34	3.86	.60	3.88	.51	3.87	.55	0.02	0.04
50	31	3.63	.51	3.82	.47	3.72	.50	0.19	0.38
Not identified	1	3.11	NA	3.09	NA	3.10	.02	−0.02	NA
Total N	132	3.84	.60	3.96	.50	3.90	.56	0.12	0.21

within CS learning derived from existing literature (Wing 2006; Kafai and Burke 2014; Jona et al. 2014; Weintrop et al. 2016) and national organizations such as the Computer Science Teachers Association (CSTA) (2011) and ISTE (2011) that encouraged develop-ment of CT into interdisciplinary curricular components.

4 Results

Inferential statistics were carried out to determine changes in the computational thinking assessment, elementary-aged students' perceptions of STEM, their enjoyment in related tasks, and career aspirations. Results from the computational thinking assessment included the 183 paired participants who were matched on the two tests. Percentages correct increased for all teachers and the changes were significant for five teachers ($p < .0038$, with a Bonferroni correction for familywise error) and the overall increase from pre- to post-test was significant ($t[182df] = 9.62, p < .0001$).

Table 1 indicates positive increases for each assessment construct except for the second loop question (Item 6) and the first debugging question (Item 7). These questions required a two-step process which likely presented confusion for students. Revision on the assess-ment will include one-step procedures for future administration. Mean scores for pre- and post-test items on the STEM survey for final paired responses included 132 students from the five schools and included in Table 2.

The table above addresses the change in overall scale mean per school with the final col-umn indicating a change as proportion of the pooled standard deviation. The paired *t* test sample was split almost perfectly between boys (N = 67) and girls (N = 65).

Other results denote differences in perceptions of STEM for males and females (Table 3), changes in perceptions over time across categories (Table 4), and perceptions about individual STEM subjects (Table 5) from pre- to post-test of the STEM survey. Table 3 indicates that males had somewhat more positive attitudes toward STEM per-ceptions overall and made slightly greater gains than females. Table 4 shows regression

Table 3 Differences on overall perceptions pre- and post-tests by gender

Gender	N	Pre	SD	Post	SD	Total	SD	Δ	$Δ/SD_{tot}$
Male	67	3.96	.58	4.09	.43	4.02	.51	0.13	0.23
Female	65	3.72	.61	3.83	.54	3.78	.58	0.11	0.20

Table 4 Regression table: change over time from overall pre- and post-test

Variable	R-sq	Wald chi2 (1)	Coef.	Std. Err.	z	P ≥ z	95%	Conf. interval
Time	Within = 0.000 Between = 0.000	5.96	.1229	.0503	2.44	0.015	.0242	.2216
_cons	Overall = 0.012		3.718	.0860	43.20	0.000	3.550	3.887

Table 5 Overall students' perceptions in stem subjects over time

Subject	Pre	SD_{pre}	Post	SD_{post}	Total	SD_{tot}	Δ	Δ/SD_{tot}
Math	3.79	0.85	3.87	0.84	3.83	0.84	0.08	0.10
Engineering	3.71	0.80	3.94	0.74	3.82	0.78	0.23	0.30
Technology	3.95	0.74	4.09	0.63	4.02	0.69	0.14	0.20
Science	3.78	0.72	3.94	0.67	3.86	0.70	0.16	0.24

analysis with overall change over time (.12) to be significant finding ($z = 2.44$, $p < .05$) from pre- to post-test. The change varied with subject (science, technology, engineering, and math). The analysis looked at the subject-specific items in each of the survey sections: (a) About you (two sections of statements about feelings toward STEM), (b) Learning, (c) Learning for later, (d) Friends, (e) Parents, Goals, (f) Activities, and (g) Future Job. Finally, Table 5 indicates how students responded on perceptions of school subjects from pre- to post-test which showed positive gains for each STEM subject.

An open-ended item on the pre- and post-test survey allowed for individual responses related to job-specifics titles or roles. Responses from paired samples of 132 students were analyzed and group according to career category. Table 6 reveals an increased interest of eight responses each on computer technology and engineering jobs from pre- to post-test.

5 Supporting Themes

Students' responses on 52 semi-structured interviews were conducted during a two-week period of November 2015 that were analyzed to augment survey findings and categorized into four major themes: (a) individual STEM subject perceptions; (b) enjoyment activities related to extracurricular, STEM, and CS concepts; (c) relationship of learned CS concepts to STEM subjects; and (d) benefits of learning CS concepts to future jobs.

5.1 Theme 1: Perception of STEM Subjects

The generic descriptions from interview data on 52 students (pseudonyms used) on subject specific categories were similar for both females and males. Foundational ideas were often based on young children's topical exposure to the subject at school. Common students' representations in approximately 65% of participants' responses on different subjects when asked, "What do you think about when I say the word X." included girls' perceptions in science as experiments and mixing things; technology as computers; engineering as building things; and math as doing problems whereas boys' perceptions in science as chemistry

Table 6 Pre- and post-test responses on students' aspirations for careers

Career category	Pre-test responses	Post-test responses	Difference
Professional sports player (NFL, MLB, NBA, MLS)	15	10	− 5
Health field (doctor or physician)	3	7	+ 4
Veterinarian or pet associated	16	16	
Educator (teacher, PE, art, gymnastics, dance)	23	17	− 4
Criminal justice (police, detective, security)	9	12	+ 3
Military and air force	7	4	− 3
Computer and technology	4	12	+ 8
Scientist	12	10	− 2
Skilled trade (plumber, construction, carpenter, electrical technician)	8	10	+ 2
Engineering	8	16	+ 8
Hospitality (restaurant, hotel, bakery)	11	10	− 1
Marine life	1	1	
Other	5	4	− 1
No response/don't know	10	3	− 7
Total	132	132	

as mixing things; technology as electronics and games; engineering as fixing and building things; and math as numbers.

Boys and girls had different perceptions on subject areas that they believed they were good at in school. Sixty percent of the girls interviewed (15/25) believed that they were good at reading and writing activities in school while fifty-one percent of the boys (14/27) chose math as a targeted skilled discipline. Responses from pre- to post-test revealed that math was a favorite subject which increased from 13 to 20% of all participants surveyed. Additionally, analysis from individual items on the pre- and post-test survey highlighted in the Table 7 demonstrates the overall mean averages that increased for student's self-concept on STEM subjects (Self-con), how quickly they learned the subjects (LrnQu), excitement in learning the subjects (Exc), perceptions on peers' thoughts on STEM subjects (Peers), and perceptions of parents' influence (Prts) on the importance of learning STEM subjects.

5.2 Theme 2: Enjoyment Activities Related to Extracurricular, STEM, and CS Concepts

Students revealed diverse interests with enjoyment of out-of-school activities. Such activi-ties for girls included variations of play with friends, pets, and family; drawing activities; outside play (i.e. basketball, soccer, wall ball); and gymnastics or dance whereas boys included sports (i.e. football, soccer, kickball), video games, Legos, and hanging out with family or friends. Of all girls interviewed (N = 25), 24% were drawn to hanging out with friends, pets, or family, 40% were motivated by drawing, 16% were drawn to outside play, and another 20% were drawn to gymnastics or dance as the enjoyment activity of choice. Of all the boys interviewed (N = 27), 33% were drawn to sports; 30% were drawn to video

Table 7 Pre- and post-test mean averages on perceptions of STEM subjects: self-concept; learning quickly; excitement in learning; peers thoughts, and parent's influence

Subject	Self-con pre	Self-con post	LrnQu pre	LrnQu post	Exc pre	Exc post	Peers pre	Peers post	Prts pre	Prts post
Science	3.51	3.69	3.42	3.47	4.06	4.11	3.84	3.92	4.0	4.13
Math	3.93	3.95	3.55	3.62	3.64	3.74	3.48	3.45	4.52	4.55
Eng.	3.35	3.51	3.18	3.43	3.89	3.91	3.60	3.69	3.78	3.92
Tech	3.82	4.0	3.61	3.68	4.20	4.20	4.20	4.11	3.83	3.92

games, 22% were drawn to Legos, and 15% were motivated by social events with family and friends as the enjoyment activity of choice.

Students expressed positive reactions to the lessons and specified the fun hands-on learning each week. An overwhelmingly 96% of students interviewed (50 of 52) had positive reactions to the lessons saying words such as: "excited, really good, happy, it's fun, I'm learning new stuff, I look forward to the lessons, and I'm enjoying them. They communicated how the lessons provided opportunities to use the computers and I-pads that allowed them to play games, create, and become smarter. Students such as Matt, Nick, Carl, Melia, and Karina responded in general terms regarding their enjoyment of lessons whereas various other students were able to provide more detailed accounts of activities that resonated with them. The following responses (Personal Communication, November 2015) in Table 8 included students' demographic background (i.e. gender, age, and ethnicity) to show how lessons leveraged CS opportunities and provided equitable learning experiences during the normal part of the school day.

For the most part, lessons reverberated excitement for students with exposure of content within the realm of unplugged activities that translated to online application of those concepts using the code.org framework where students manipulated drag and drop blocks to run a designated program. Playing games that involved students moving the angry bird to the pig enhanced their CS understandings of sequence, algorithm, debugging, and loops. Thus, females were generally more expressive and specific than their male counterparts when prompted to recall lesson ideas and concepts as evident in the responses from students such as Katelyn, Kassandra, Kaiya, and Kate. Pre- and post-test surveys augmented this theme to reveal students' self-rated attitudes of STEM-related activities.

Thus, Table 9 indicates the mean increases from pre- and post-test survey where students highlighted particular activities in engineering, math, and science that they enjoyed doing.

5.3 Theme 3: Relationship of Learned CS Concepts to STEM Subjects

Students were able to make connections on how coding concepts related to certain STEM subjects (Personal Communication, November 2015). Math principles were the most relatable as both boys and girls drew connections between the subject and the learned CS con-cept as shown in Table 12 with the following comments.

As shown in the comments from Table 10, students' connections of the CS content to math concepts included representations of principles related to sequence, algorithm, and loops. For many students, understanding algorithms in math were likely appropriated from students' first exposure to the concept when learning the basic steps to solve a problem during primary grades.

5.4 Theme 4: Benefits of Learning CS Concepts to Future Jobs

Pre- and post-test data illustrated changes in students' perceptions on the important criteria for their future jobs. Table 11 illustrates positive changes for using technology, engineer-ing, and math as well as moderate changes for the usefulness of the math and science in their future jobs.

Responses related to money and fame were perceived as less important values in their future jobs. The learned CS concepts were further explored with responses from student

Table 8 Students' responses related to lesson enjoyment

Student (pseudonyms)	Demographic background	Learning response
Matt	Male, 8 years-old, White	I feel pretty good because it's fun to learn new stuff
Nick	Male, 8 years-old, White	It just makes me smarter because I'm learning something new
Carl	Male, 9 years-old, White	I feel happy cause you can learn how to use i-pads and everything
Melia	Female, 8 years-old, African American	My favorite part is trying to program the games
Karina	Female, 9 years-old, Latina	I feel real good because I get to learn new things I never knew
Beau	Male, 8 years-old, White	It's fun. I always look forward to Friday. I like learning how to type really fast and learning how to use my mouse. It's fun to use your little character. Code.org is a really fun place
Carter	Male, 9 years-old, White	They are sort of fun. Trying to put things and make them work
Darius	Male, 9 years-old, African American	My favorite part is when we do the mazes. We use these words and use repeat blocks, and forward blocks, left blocks, right blocks. And we try to get whatever into where it is supposed to be
Marsha	Female, 8 years-old,	It's fun when we go on the tablets. They are games that you learn when the teacher writes things on the board
Harriet	Female, 8 years-old, White	I feel really, really good! My favorite part is the zombies part! You have these blocks that say, "repeat times" and then you put a move forward, turn or do something in that box and you get to click on that box with the question mark and you get to type which number. And sometimes you don't get it right on the first time, but you get it right on the second, or third or whatever
Katelyn	Female, 9 years-old, White	I like them…Playing the games and breaking the codes. Well, today it shows arrows and scribbles and stuff to show to color it or move. We were trying to figure out which part there was something wrong
Kaiya	Female, 8 years-old, Asian-American	I like them. I like when we got to do a dance. Yeah, we play an angry birds game. There's also different levels, you try to get the angry bird to the egg and there's the bee that you have to collect honey. And you have to make honey. These are steps. There's like front, forwards, left, right and there's the make honey one, and the collect nectar, and there's one where you can put like you have to put forward two times. You just put one forward in there and there's this little box type whatever and you put how many times you need to repeat it. Instead of just doing two
Kate	Female, 8 years-old, White	The lessons are fun because you get to play on the computer and you get to move a character. And if you find a mistake you can pull the mistake out or add something to make the mistake right
Jenny	Female, 8 years-old, White	I'm enjoying them. It's my favorite part when we can play the games and write. We're doing like angry birds. On a computer, you put move forward and then right and you try to get the pig
Kassandra	Female, 8 years-old, White	I feel really excited when I get to do coding because it's really fun. I like the part where in the previous lesson my favorite part was where he had us dance and make our own dance things. I like to do activities that involve moving and sports and that kind of thing

interviews which suggest how students were able to connect learned CS content to impor-tant contributions in future careers. These comments are displayed in Table12.

6 Discussion

The results from this exploratory study capture the importance of promoting types of learning experiences necessary to influence students' self-concept, attitudes, and perceptions about STEM/CS content. Early intervention and exposure to STEM/CS activities can cultivate positive perceptions and attitudes toward STEM. Exposure to the CS lessons allowed students to attain basic computational thinking knowledge as well as an opportunity to learn new ideas through discovery and construction of new ideas. As Wing (2006) suggested for fostering CT skills, students in the study developed "metal and mental" tools gained from CT concepts to use appropriate technology skills to solve problems with the correct codes for the online puzzles and acquired the intellectual capacity to understand CS connections to the everyday world (Grover and Pea 2013). These relationships were evident in students' responses such as: (a) Betty, with her explanation of learning the essential components of algorithms to support the steps used in finding a cure in her future aspiration as a doctor; (b) Kassandra as she connected with the debugging concept and the importance of trial and error in her future job as an anesthesiologist who could potentially administer the wrong dosage of drugs to a patient causing death; and (c) Beau, who extrapolated from the idea of a running a computer program moving from simple to complex codes by creating a 3D model instead of a paper created one-dimensional figure. The CT elements revolved around problem-solving, mathematical skills, and creative design that students learned from the CS lessons supported CSTA and ISTE operational definitions of CT (2011) and research reinforcing how CS opportunities provided unique extensions for students' higher-order thinking skills that are necessary in today's world (Barr and Stephenson 2011).

Moreover, this exposure supported students' interdisciplinary thinking as they began to consider how concepts related to a variety of STEM topics and disciplines. For many participants, CS concepts taught critical thinking skills that were essential to understanding core mathematical principles. These principles included breaking down problems into chunks and manipulating them into small parts. In primary grades, students' base in grasping computational thinking were derived from early learning experiences and math exercises. Such events comprised of the basics of breaking down a math problem into simple step-by-step instructions to perform the function and arise to the answer. Familiar algorithms for students at this age group in elementary school included addition, subtraction, multiplication, and division problems. The CS concepts that students were learning were relatively basic; however, they were critical foundational ideas to support students' connections to math and other content areas including applications for practical use in everyday life. This knowledge of CS echoes several past scholars' work on the benefits of developing literacies in computational thinking such as: Gover and Pea's (2013) review of CS within K-12 platforms on its benefits of abstraction skills created through algorithmic procedures; diSessa (2000) and Wolfz's (2011) vision of CT as an essential expressive language for reading and writing; and Resnick's (2006) view that computational thinking enables new ways of thinking. The development of these concepts allowed the participants in the study to express the language of math within relevant ways, share the language of math across

Table 9 Pre- and post-test responses on enjoyment of stem-related activities

Subject	STEM-related activity	Mean pre-test	Mean post-test
Engineering	I enjoy taking things apart and putting them back together	3.73	3.76
Engineering	I enjoy building and creating things	4.43	4.51
Math	I enjoy doing math in my free time	3.18	3.31
Math	I enjoy doing math whenever I see them	3.24	3.52
Science	I enjoy doing experiments in science	4.23	4.32

contexts, and integrate interdisciplinary concepts given that CS was the core of all STEM disciplines (Henderson et al. 2007).

Motivational factors from students' parents served as critical markers in students' self-concept, beliefs, and encouragement. Students' parents were aware of the learning activities during the intervention period and could have exerted influence on their children's learning with regard to STEM/CS disciplines. Thus, as shown in Table 7, students' ratings increased from pre- and post-test surveys indicating the likelihood of parental motivational influence for them studying a STEM subject. With continual encouragement, parents do play a role in students' decision-making process for future study and careers. Strong parent and child relationships can foster the decisions that students make, often with more willingness to be receptive to their parents' advice, given the positive perceptions about the level of support they receive from their parents (Tziner et al. 2012). Thus, schools should exercise attention to the range of parental activities that support students' intrinsic motivation in STEM and CS content, achievement, and persistence in those careers. Such activities involve an initiative for teachers to engage parents at school with back-to-school nights that facilitate planned demonstrations and sessions around STEM and CS learning. Teachers can persuade parents who are representative of the school population to serve as STEM/CS community or industry speakers, which could likely increase the effect of parents' roles. When teachers and parents work together, students do emerge as winners as they view their parents as partners of their academic journey and success (Tran 2014).

Contextual conditions of how students received the exposure might have also influenced students' perceptions. Past research has suggested the role of classroom learning environments and how they relate to students' attitudes toward science specifically (Lawrenz 1976; Simpson and Oliver 1990; Riah and Fraser 1997; Aldoplhe et al. 2003). These authors specified that supportive classroom environments were strong predictors and positively correlated to students' perceptions of STEM and CS. Certain pedagogical effects within the environment where preservice teachers delivered lessons through a hybrid model of the intervention may have affected students' perceptions given their reactions to the lessons and enjoyment of varied concepts explored during the intervention. These results were captured in the Table 8 when students such as Kaiya and Kassandra described the dance strategy when learning about the concept of loop. Beau, Darius, Harriet, and Katelyn also made references to their motivation and excitement in coding given the opportunity to use technology tool to work through the online puzzles. Research has suggested the effectiveness of learning engagement and related outcomes through hybrid approaches (Kuo et al. 2014; Reynard 2003). Intentional planning and delivery of lesson concepts maximized traditional approaches with online puzzles to allow students to experience learning from both environments. Within the standard

Table 10 Students' responses of CS learning related to stem subjects

Student (pseudonyms)	Demographic background	Learning response
Bonnie	Female, 9 years-old, White	Like a pattern of how you do it, it's important in math
Jenny	Female, 8 years-old, White	It's helping me with math because of learning steps
Luke	Male, 8 years-old, Latino	It (coding) is important in math cause some of the words they use in there are kind of like the mathematical words. So, I can't remember all the words they say in there, but I think looping can be kind of like a math word. And they have a lot of words that I think could be math
Dave	Male, 9 years-old, Latino	Well, math. I'm planning since I finished the first one, I'm going to do the second one. It's angles so I'm pretty sure we're going to learn that soon. And right now, I think the best part in coding that I'm best about was steps. When we made paper airplanes mine was perfect and I threw it all to way across the room. You put blocks inside of a pink thing and it says up on top, "Repeat how many times". And you click on it and how many times you want to repeat it, that's how many times it does
Catelyn	Female, 8 years-old, White	Math because she explains it to us. Like multiplication strategies. It's like normal and it's easy to use with coding because of the strategies and steps
Carla	Female, 9 years-old, Latina	We just learned that definition that I think we did with math. Like an algorithm…It's really important for business and every business really has math and writing. You have to write stuff and math you have to do
Grace	Female, 8 years-old, White	It helps us with math because you have to go like plus how many steps you want the bird to go to get to the pig and not running into TNT and blowing up
Betty	Female, 8 years-old, Latina	I guess like we're doing some papers where we have to put it in the right spot and that's basically an algorithm, because it's a list of instructions or things that happen over and over again
Mark	Male, 8 years-old, White	Math. If you are playing a game that involves a code like angry birds you have to figure out the code. Like how far you have to pull the angry bird and what spot you have to launch it at
Oakley	Male, 8 years-old, African-American	It's important for my knowledge of computers. You need to figure out the angles and how many times you want it to repeat. It'll help me to know more about computers so that if I make a mistake, I'll know.

Table 11 Pre- and post-test responses on importance in learning for future job

Future job: important criteria	Mean pre	Mean post
Use technology	3.84	3.95
Use math	3.86	4.07
Use science	3.70	3.72
Use engineering	3.59	3.69
Usefulness of math	4.14	4.27
Usefulness of science	3.84	4.02
Be famous	3.08	2.88
Make a lot of money	4.18	4.01

learning environment on a typical lesson day of the intervention, specific content was presented and modeled so that students can explore, interact, or ask questions to keep engagement high. Several examples included how students interacted with the concept of loops through a dance with repeated instructions; engaged in an outside relay activity to debug a program; or created paper airplanes within algorithmic procedures. These activities excited students that widened participation and appropriated a sense of pleasure within the learning experience. The preservice teachers provided scaffolds to support students' learning and transfer of the knowledge gained to online applications to problem solve and create codes by manipulating the drag and drop blocks. This scaffolding and blended learning approach has been supported by some researchers (Rosenshine and Stevens 1992; Westermann 2014; Lou et al. 2012) who suggested preparing students for higher-level cognitive thinking through loose structured interactive environments where teachers model concepts then students to apply learned material to a platform for self-directed learning and construction of new ideas. Shifts from teacher control to student control fostered changes in attitudinal development as learners' gain more agency and efficacious behaviors of their own work.

Furthermore, given that students in the study generally had constructive views of STEM subjects with optimistic ideas of how CS influences their future jobs, embedding this type of learning into the primary curriculum can be beneficial for students' learning trajectory increasing their breadth of STEM/CS from an early age. As indicated in the comments provided in Table 12, the exposure of the CS lessons supported students' understanding of its purpose and connection to a future job. The CS learning activities that students explored during the intervention developed problem-solving, critical thinking, and valuable attitudes that encouraged a possible career in STEM as referenced by Betty who described how scientists use coding; Kassandra who described how an anesthesiologist would use coding to reduce error in administering the wrong chemicals to a patient; and Beau's use of coding as a way to outline his invention onto a computer. These examples provide a fitting impetus for prioritizing CS opportunities early as they nurtured healthy STEM attitudes and career aspirations for children between 8 and 11 years-old which were echoed by scholars (Murphy and Beggs 2003; Archer et al. 2013). The quantitative results from Table 11 augment the need to provide early exposure of CS given the positive increases from pre- to post-test survey that captured students' changes in the usefulness of learning each STEM subject to a future career. Moreover, students emphasized the significance for using math and science as valuable criteria for their future jobs rather than the acquisition of fame or wealth given their positive attitudes and increases from pre- to post-test scores.

Table 12 Students' responses related to future jobs

Student (pseudonyms)	Demographic background	Learning response
Betty	Female, 8 years-old, Latina	Cause scientists also have to follow algorithms to get the right stuff. Like if they are doing an experiment to get like a cure or something they need to follow some instructions to get the right things into that cure
Cabe	Male, 8 years-old, White	Maybe if you have a job and you're doing it over and over again like the weather…It could be because you could build, build, build over again or instructions because first you could plan it out and then build
Zeus	Male, 9 years-old, Latino	If I don't learn about anything else I wouldn't be able to complete what we are talking about and I won't know what we are going to do. So for loops if you're a grownup and if your boss came to tell you something three times then you would be complete it
Carla	Female, 9 years-old, Latina	Coding is important if you want to be, every job may be with a computer, you have to know how to work with technology
Kate	Female, 8 years-old, White	Like if you wanted to be video game person and you wanted to design video games
Kassandra	Female, 8 years-old, White	Because it would help me (as anesthesiologist) about how much I should do with the chemicals. Because if I give them too much they could die and never wake up or if don't give them enough they could wake up during the surgery and feel it and that would hurt
Beau	Male, 8 years-old, White	If we ever get a job like an inventor we're going to need to be able to do these things. We need to be able to get into these things and make our ideas into the computer. So, I could have a 3D model instead of having to make it out of paper or stones or something
Tom	Male, 8 years-old, White	It shows you some things about life like how it can be and how you can get better ways to go forward in life. Learning about coding going to be helpful for your SWAT job later if I'm one of those tech people, like how to hack into other people's houses and know where they live

Different engagement activities to encourage interaction for boys and girls are also critical when considering ways to elicit enjoyment for students. Boys interviewed in the study (more than 80%) were drawn to construction, video games, sports, and perceived themselves as decent with math; while girls interviewed (more than 60%) were drawn to drawing, art, social activities with friends and family, and perceived themselves as confident in the reading domain. Participation in the CS learning provided collaboration for students to problem solve, explore concepts, and construct knowledge. Taking into consideration the varied interests and efficacy beliefs between genders, it would be beneficial to continue promoting specific CS learning activities related to the individual subject areas to increase students' confidence and enjoyment. For example, girls might appreciate reading expository texts about the different STEM disciplines as well as famous individuals who have contributed to society through altruistic behaviors involving STEM/CS careers. Boys could likely relish in problem-solving activities that involve math or opportunities to construct their own story problems involving sports themes. Regardless of the activity, it is critical to consider the activity as part of the wider STEM integration plan (NRC 2009, 2012; Sanders 2009) to increase student interest, motivation, and achievement in these disciplines. Providing for in-school learning activities with similar CS concepts taught between and among the different STEM content areas are potential ways to improve student enthusiasm and drive. For example, in one lesson, students learned the CS concept of loops through a repeated dance activity, explored the relationship of loops in math, discussed evidence of them in real-life, and made applications online as well as in broader contexts. Using similar methods, instruction of concepts can include unplugged activities by merging STEM disciplines that deepen student learning by contextualizing concepts, broadening student understanding with culturally relevant contexts, expanding interdisciplinary content conversations for critically thinking, and recognizing acclaimed achievements from females and males who have contributed to the STEM/CS career pipeline. In this way, integration becomes entrenched and part of the existing classroom learning; a culture that taps into specific students' interests and widely accommodated for all students. It is within this paradigm that learning leverages access during in-school time by promoting equity to increase participation for girls and boys that heightens awareness of STEM/CS while building positive perceptions of those disciplines and promoting capital for future job aspirations.

Providing hands-on activities, conducting science experiments in the classroom, and making math relevant to real-life for students can be motivational ways to influence learning. These activities allow students to exercise mental abilities that challenge them as well as acquire meaning. Thus, meaningful learning involved taking new ideas and concepts by integrating them into existing concepts and structures (Ausubel 1963). The CS lessons were designed and delivered interdisciplinary in math, science, or language arts content time by activating students' prior knowledge of concepts and relating them into real-life events. Students were then expected to transfer the information into unplugged learning tasks to create meaning while applying those concepts to online puzzles. Integration of concepts with the hybrid approach supported students' acquisition that translated into authentic learning sets rather than isolated memorization of facts. Early exposure of CS content across disciplines remains crucial starting in primary school so that children learn how lessons are connected to other curricular areas as well as their current and future lives. Finally, teachers need specific trainings as they learn how to use CS as a medium for instruction of other subjects and scaffold those understandings to their students.

7 Conclusion

The urgency to strengthen STEM in K-12 has translated into much funded research by federal organizations, foundations, and private corporations such as NSF, U.S. Department of Education, Society of Women Engineers, Gates Foundation, Google, and Intel. While these initiatives have broadened STEM participation for students in K-12; CS education has remained underfunded. Much remains inconclusive about when and how to teach CS in K-12 although efforts are gaining momentum to raise consciousness of the need in schools. New research, policy, and initiatives will help to inform pedagogical approaches including appropriate curricula for students as well as effectively preparing teachers for CS education.

As CS education becomes an imperative within K-12 classrooms, this study sheds light into a topic that has been largely untapped in the literature regarding elementary-aged students' perceptions, career choices, exposure, and interest in STEM/CS disciplines. The findings suggest that early exposure to CS content as a way to enrich computational literacy around creativity, flexibility, and collaboration while enhancing problem solving skills across content areas. Fostering computational thinking skills can promote enthusiastic perceptions for STEM/CS career choices later. Essentially, it is important to shift STEM/CS into a culture that embraces it into everyday curriculum with experiential opportunities to nurture learning activities that meet varied students' interests. These experiences leverage opportunities to allow students to gain confidence, persistence, and develop self-efficacy in CS integrated concepts, ultimately, empowering students to reach their own potential for greatness. Continued research remains necessary to determine factors related to successful STEM/CS intervention programs as well as effective methods to support students' varied interests, access, and implications across language, socioeconomic, and ethnic backgrounds including long-term gains on students' educational and career trajectories.

Appendix 1

Example Questions from Computational Test

Put these mixed-up instructions for baking a cake in order using only four steps. Write numbers 1–4 next to those steps.

- Make a salad. ______
- Pour batter into pan. ______
- Eat half of the batter. ______
- Mix ingredients in a bowl. ______
- Drink some water. ______
- Bake for 20 min. ______
- Measure ingredients. ______

Emma is exercising before gym class. Emma does two push-ups. Emma repeats the first step three times, and touches her toes once after each repeat. How many push-ups did Emma do? ________

How many times did she touch her toes? __________

Circle the wrong steps in the sequence.

- Wake up.
- Get dressed and eat breakfast.
- Drive to school
- Put on your backpack for school.
- Get in the car.
- Walk into the classroom.

Appendix B

Example Items from Survey Instrument

1 = strongly disagree	2 = disagree	3 = neutral	4 = agree	5 = strongly agree

(Self-concept related to STEM)
I am good with technology.
I am good with science.
I am good with math.
I am good with engineering (design or inventions).

(Perceptions of learning STEM)
I learn things quickly in math lessons.
I learn things quickly in technology lessons.
I learn things quickly in science lessons.
I learn things quickly in engineering lessons (design or inventions).

(Learning about STEM for later)
Studying science is useful for getting a good job in the future.
Studying engineering (design or inventions) is useful for getting a good job in the future.
Studying science is useful for getting a good job in the future.
Studying technology is useful for getting a good job in the future.
Studying math is useful for getting a good job in the future.

(Parents' attitudes about STEM)
My parents think it is important for me to learn about technology.
My parents think it is important for me to learn about engineering (design or inventions).
My parents think it is important for me to learn about science.
My parents think it is important for me to learn about math.

(Goals/aspirations in STEM)
I would like to study more about technology in the future.
I would like to study more about math in the future.
I would like to study more about engineering (design or inventions) in the future.
I would like to study more about science in the future.

(Future job-STEM related)
It is important for me to use technology in my future job.
It is important for me to use math in my future job.

It is important for me to use science in my future job.
It is important for me to use engineering (design or inventions) in my future job.

Please write down some answers to these questions

What kind of job do you want when you grow up?
What makes this job enjoyable to you?

Circle one

Are you a boy or girl?	BOY	GIRL

References

Aldoplhe, F. S. G., Fraser, B. J., & Aldigre, J. M. (2003). A cross national study of learning environment and attitudes among junior secondary science students in Australia and Indonesia. *Paper presented at the Third International Science, Mathematics, and Technology Education Conference, East London, South Africa*.

Anderman, E. R., & Young, A. J. (1994). Motivation and strategy use in science: Individual differences and classroom effects. *Journal of Research in Science Teaching, 31,* 811–831.

Andersen, M. (2005). Thinking about women: A quarter century's view. *Gender and Society, 19*(4), 437–455.

Archer, L., Osborne, J., DeWitt, J., Dillon, J., Wong, B., & Willis, B. (2013). *ASPIRES Young peoples' science and career aspirations, age 10–14*. London: Department of Ducation and Professional Studies. King's College.

Auger, R. W., & Blackhurst, A. E. (2005). The development of elementary-aged children's aspirations and expectations. *American School Counselor Association Journal, 8*(4), 322–329.

Augustine, N. R. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: The National Academies Press.

Ausubel, D. (1963). *The psychology of meaningful verbal learning*. New York: Grune & Stratton.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28,* 117–148.

Bandura, A., Barbarenelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development, 72*(9), 187–206.

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: What is involved and what is the role of the computer science community? *ACM Inroads, 2*(1), 48–54.

Barshay, J. (2011). 'Blended learning' for the little ones. *Education Week, 31*(9), 1–14.

Bell, T., Witten, I., & Fellows, M. (2011). Computer science unplugged. Retrieved from http://csunplugged.org/books/. Accessed 15 Aug 2015.

Bers, M. U. (2010). The TangibleK robotics program: Applied computational thinking for young children. *Early Childhood Research & Practice, 12(2)*. Retrieved from http://ecrp.uiuc.edu/v12n2/bers.html.

Bers, M., & Horn, M. (2010). Tangible programming in early childhood: Revisiting developmental assumptions through new technologies. In I. Berson & M. Berson (Eds.), *High-tech tots: Childhood in a digital world* (pp. 49–70). Charlotte, NC: Information Age Publishing.

Boyles, S. R. (2011). Using technology in the classroom. *Science Scope, 34*(9), 39–43.

Campbell, G., Denes, R., & Morrison, C. (Eds.). (2000). *Access denied. Race, ethnicity, and the scientific enterprise*. Oxford: Oxford University Press.

Cavallo, A. M. L. (1996). Meaningful learning reasoning ability and student's understanding and problem of genetics topics. *Journal of Research in Science Teaching, 38,* 625–656.

Cavallo, A. M. L., Rozman, M., & Potter, W. H. (2004). Gender differences in learning Constructs, shifts in learning constructs, and their relationship to course achievement in a structured inquiry, yearlong collage physic course for life science majors. *School Science and Mathematics, 104*(6), 288–301.

Center of Digital Education. (2013). Center for digital education digital content and curriculum comprehensive report. Retrieved September 1, 2016 from http://www.centerdigitaled.com/awards/digital-content-curriculum/2013awards.html.

Chen, X. (2009). *Students who study science, technology, engineering, and mathematics (STEM) in postsecondary education (NCES 2009-161)*. Washington DC: National Center for Educational Statistics.

Cinamon, R. G., & Dan, O. (2010). Parental attitudes toward preschoolers' career education: A mixed-method study. *Journal of Career Development, 37,* 519–540.

Clements, D. H. (1987). Longitudinal study of the effects of logo programming on cognitive abilities and achievement. *Journal of Educational Computing Research, 3,* 73–94.

Clements, D. H., Battista, M. T., & Sarama, J. (2001). Logo and geometry. *Journal of Research in Mathematics Education Monograph Series*, 10.

Committee on Science, Engineering, and Public Policy. (2007). *Rising above the gathering storm: Energizing and employing America for a Brighter economic future*. Washington DC: The National Academies Press.

Correll, S. J. (2001). Gender and the career choice process: The role of biased self-Assessments. *The American Journal of Sociology, 106*(6), 1691–1730.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage.

CSTA. (2011). Operational definition of computational thinking for K-12 education. Retrieved from http://www.csta.acm.org/Curriculum/sub/CompThinking.html. Accessed 1 July 2017.

DeJarnette, N. K. (2012). America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives. *Education, 133*(1), 77–84.

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related aspirations across the primary-secondary divide: Evidence from two surveys in England. *International Journal of Science Education, 36*(10), 1609–1629.

DiSessa, A. A. (2000). *Changing minds: Computers, learning, and literacy*. Cambridge: MIT Press.

Duschl, R. A., Schweinggruber, H. A., & Shouse, A. W. (2007). *Taking science to school: Learning and teaching science in Grades K-8*. Washington, DC: National Academy Press.

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Motivation. In N. Eisenberg (Ed.), *Handbook of child psychology* (5th ed., Vol. 3, pp. 1017–1095). New York: Wiley.

Edmondson, K. M. (1989). *The influence of students' conceptions of scientific knowledge and their orientations to learning on their choices of learning strategy in a college introductory level biology course*. Unpublished doctoral dissertation, Cornell University, Ithaca, NY.

Elkind, D. (1982). Piagetian psychology and the practice of child psychiatry. *Journal of the American Academy of Child Psychiatry, 21,* 435–445.

Fessakis, G., Gouli, E., & Mavroudi, E. (2013). Problem solving by 5-6 years old kindergarten children in a computer programming environment: A case study. *Computers & Education, 63,* 87–97.

Ginzberg, E. (1952). Toward a theory of occupational choice. *Occupations, 30,* 491–494.

Glaser, B. G., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. New York: Aldine.

Gottfredson, L. (1981). Circumscription and compromise: A developmental theory of occupational aspirations [Monograph]. *Journal of Counseling Psychology, 28*, 545–579.

Gottfredson, L. S., & Lapan, R. T. (1997). Assessing gender-based circumscription of occupational aspirations. *Journal of Career Assessment, 5*(4), 419–441.

Gottfried, A. E. (1990). Academic intrinsic motivation in young elementary school children. *Journal of Educational Psychology, 82,* 525–538.

Grover, S., & Pea, R. (2013). Computational thinking in K-12: A review of the state of the field. *Educational Researcher, 42,* 38–43.

Harackiewiez, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of utility-value intervention. *Psychological Science, 23,* 899–906.

Harris, C. J., & Rooks, D. L. (2010). Managing inquiry-based science: Challenges in enacting complex instruction in elementary and middle school classrooms. *Journal of Science Teacher Education, 21,* 227–240.

Henderson, P. B., Cortina, T. J., Hazzan, O., & Wing, J. M. (2007). Computational thinking. In *Proceedings of the 38th ACM SIGCSE technical symposium on computer science education (SIGCSE'07)* (pp. 195–196). New York, NY: ACM Press.

Holland, J. L. (1985). *Making vocational choices* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Hong, S. (2010). The reciprocal relationship between parental involvement and Mathematics achievement: Autoregressive cross-lagged modeling. *Journal of Experimental Education, 78,* 419–439.

Horn, M. S., Crouser, R. J., & Bers, M. U. (2011). Tangible interaction and learning: The case for hybrid approach. *Personal and Ubiquitous Computing, 16*(4), 379–389.
Horn, M. B., & Staker, H. (2011). The rise of K-12 blended learning. Innosight Institute. Retrieved September 1, 2016 from http://www.innosightinstitute.org/mediaroom/publications/education-publications.
Ing, M. (2014). Can parents influence children's mathematics achievement and persistence in STEM careers? *Journal of Career Development, 41*(2), 87–103.
International Society for Technology in Education and the Computer Science Teachers Association. (2011). Operational definition of computational thinking for K-12 Thinking operational-defintiion-flyer.pdf. Retrieved from http://www.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf?sfvrsn=2. Accessed 1 July 2017.
International Society for Technology in Education and the Computer Science Teachers Association. (2017). Computational thinking teacher resources. Retrieved from http://www.iste.org/docs/ct-documents/ct-teacher-resources_2ed-pdf.pdf?sfvrsn=2.
Israel, M., Pearson, J. N., Tapia, T., Wherfel, Q. M., & Reese, G. (2015). Supporting all learners in school wide computational thinking: A cross case qualitative analysis. *Computers & Education, 82,* 263–279.
Jona, K., Wilensky, U., Trouille, L., Horn, M. S., Orton, K., Weintrop, D., & Beheshti, E. (2014). Embedding computational thinking in science, technology, engineering, and math (CT-STEM). *Presented at the Future Directions in Computer Science Education Summit Meeting, Orlando, FL.*
Kafai, Y. B., & Burke, Q. (2014). *Connected code: Why children need to learn programming*. Cambridge: MIT Press.
Kazakoff, E., Sullivan, A., & Bers, M. U. (2013). The effect of a classroom-based intensive robotics and Programming workshop on sequencing ability in early childhood. *Early Childhood Education Journal, 41*(4), 245–255.
Kuo, Y., Belland, B. R., Schroder, K. E., & Walker, A. E. (2014). K-12 teachers' perceptions of and their satisfaction with interaction type in blended learning environments. *Distance Education, 35*(3), 360–381.
Lawrenz, F. (1976). Student perception of the classroom learning environment in biology, chemistry and physics courses. *Journal of Research in Science Teaching, 13*(4), 315–323.
Lederman, N. G., & Lederman, J. S. (2013). Is it STEM or" S & M" that we truly love? *Journal of Science Teacher Education, 24*(8), 1237.
Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., et al. (2011). Computational thinking for youth in practice. *ACM Inroads, 2,* 32–37.
Liao, Y.-K., & Bright, G. (1991). Effects of computer-assisted instruction and computer programming on cognitive outcomes: A meta-analysis. *Journal of Educational Computing Research, 7*(3), 251–268.
Lou, S., Chen, N., Tsai, H., Tseng, K., & Shih, R. (2012). Using blended creative teaching: Improving a teacher education course on designing materials for young children. *Australasian Journal of Educational Technology, 28*(5), 776–792.
Ma, X. (1999). Dropping out of advanced mathematics: The effects of parental involvement. *Teachers College Record, 101,* 60–81.
Ma, X. (2001). Participation in advanced mathematics: Do expectation and influence of students, peers, teachers and matter? *Contemporary Educational Psychology, 26,* 132–146.
Magnuson, S. J., & Palincsar, A. S. (2005). Teaching to promote the development of scientific knowledge and reasoning about light at the elementary level. In M. S. Donovan & J. D. Bransford (Eds.), *How students learn science in the classroom* (pp. 53–106). Washington DC: National Academy Press.
Magnuson, C., & Starr, M. (2000). How early is too early to begin life career planning? The importance of the elementary school years. *Journal of Career Development, 27*(2), 89–101.
Middleton, E. B., & Loughead, T. A. (1993). Parental influence on career development: An integrative framework for adolescent career counseling. *Journal of Career Development, 19,* 161–173.
Mioduser, D., Levy, S., & Talis, V. (2009). Episodes to scripts to rules: Concrete abstractions in kindergarten children's explanations of a robot's behaviors. *International Journal of Technology and Design Education, 19*(1), 15–36.
Moomaw, S. (2012). STEM begins in the early years. *School Science and Mathematics, 112*(2), 57–58.
Murphy, C., & Beggs, J. (2003). Children's perceptions of school science. *School Science Review, 84,* 109–116.
Nagy, G., Trautwein, U., Baumert, J., Koller, O., & Garrett, J. (2006). Gender and course-selection in upper secondary education: Effects of academic self-concept and intrinsic value. *Educational Research and Evaluation, 12*(4), 323–345.
National Academy of Sciences. (2007). *Beyond bias and barriers: Fulfilling the potential of women in academic science and engineering*. Washington DC: The National Academies Press.

National Academy of Sciences. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category* (Vol. 5). Washington DC: The National Academies Press.

National Research Council (NRC). (2009). *Engineering in K–12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Newhouse, N. (1990). Implication of attitudes and behavior research for environmental Conservation. *The Journal of Environmental Education, 22*(1), 26–32.

Oh, P. S., & Yager, R. E. (2004). Development of constructivist science classrooms and changes in student attitudes toward science learning. *Science Education International, 15*(2), 105–113.

Oregon Department of Education. (2015). School and District Report Cards. Retrieved from https://www.ode.state.or.us/data/reportcard/reports.aspx. Accessed 1 July 2017.

Papanastasiou, C., & Papanastasiou, E. C. (2004). Major influences on attitudes toward science. *Educational Research and Evaluation, 10*(3), 239–257.

Papanastasiou, E. C., & Zemblyas, M. (2002). The effects of attitudes on science achievement: A study conducted among high school students in Cyprus. *International Review of Education, 48*(6), 469–484.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Pintrinch, P., & Schunk, D. (2002). *Motivation in education*. Upper Saddle River: Merrill Prentice Hall.

Program for International Student Assessment. (2012). Retrieved from https://nces.ed.gov/surveys/pisa/pisa2012/index.asp.

Puacharearn, P., & Fisher, D. (2004). *The effectiveness of cooperative learning integrated with constructivist teaching on improving learning environments in Thai secondary school science classrooms*. Bentley: Curtin University of Technology.

Reigle-Crumb, C., Moore, C., & Ramos-Wada, A. (2010). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95,* 458–476.

Resnick, M. (2006). Computer as paintbrush: Technology, play, and creative society. In D. Singer, R. Golikoff, & K. Hirsh-Pasek (Eds.), *Play = learning: How play motivates and enhances children's cognitive and social-emotional growth*. New York, NY: Oxford University Press.

Reynard, R. (2003). Internet-based ESL for distance adult students—A framework for dynamic language learning. *Canadian Modern Language Review, 60*(2), 123–143.

Riah, H. & Fraser, B. J. (1997). Chemistry learning environment in Brunei Darussalam's secondary schools. In D.L. Fisher & T. Richards (Eds.), *Science, Mathematics and Technology Education and National Development: Proceedings of the Vietnam Conference* (pp. 108–120). Hanoi.

Roe, A. (1957). Early determinants of vocational choice. *Journal of Counseling Psychology, 4,* 212–217.

Rosenshine, B. & Stevens, R. (1992). The use of scaffolds for teaching less structured academic tasks. *Paper presented at the annual meeting of the American Educational Research Association, San Francisco*.

Sanders, M. (2009, December/January). STEM, STEM education, STEMmania. *The Technology Teacher*, 20–26.

Seligman, L., & Weinstock, L. (1991). The career development of 10 year olds. *Elementary School Guidance and Counseling, 25*(3), 172–182.

Simpson, R. & Oliver, J. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*(1), 1–18.

Splete, H., & Freeman-George, A. (1985). Family influences on the career development of young adults. *Journal of Career Development, 12,* 55–64.

Strauss, C. (1992). What makes Tony run? Schemas as motive reconsideration. In R. D'Andrade & C. Strauss (Eds.), *Human motives and cultural models* (pp. 191–224). Cambridge: Cambridge University Press.

Strauss, C., & Quinn, N. (1997). *A cognitive theory of cultural meaning*. Cambridge: Cambridge University Press.

Tai, R., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312,* 1143–1144.

Tran, Y. (2014). Addressing reciprocity between families and schools: Why these bridges are instrumental for students' academic success. *Improving Schools Journal, 17*(1), 18–29.

Trends in International Mathematics and Science Study. (2011). TIMSS international results in mathematics. Retrieved March 6, 2015 from http://timss.bc.edu/timss2011/downloads/T11_IR_M_Chapter1.pdf.

Trice, A. D., Hughes, M. A., Odom, C., Woods, K., & McClellan, N. C. (1995). The origins of children's career aspirations: IV. Testing hypotheses from four theories. *Career Development Quarterly, 43*, 307–322.

Trice, A. D., & McClellan, N. (1993). Do children's career aspirations predict adult occupations? An answer form a secondary analysis of longitudinal study. *Psychological Reports, 72,* 368–370.
Trice, A. D., & Tillapaugh, P. (1991). Children's estimates of their parents' job satisfaction. *Psychological Reports, 69,* 63–66.
Trusty, J. (1996). Relationship of parental involvement in teens' career development to teens' attitudes, perceptions, and behavior. *Journal of Research and Development in Education, 30,* 65–69.
Tziner, A., Loberman, G., Dekel, Z., & Sharoni, G. (2012). The influence of parent off spring relationship on young people's career preferences. *Psicologia del Trabajo y de las Organizaciones, 28*(2), 99–105.
Wahyudi, W., & David, F. T. (2004). The status of science classroom learning environments in Indonesian lower secondary schools. *Learning Environment Research, 7,* 43–63.
Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., et al. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology, 25*(1), 127–147.
Westermann, E. B. (2014). A half-flipped classroom or an alternative approach?: Primary sources and blended learning. *Educational Research Quarterly, 38*(2), 43–57.
Wilensky, U., Brady, C., & Horn, M. (2014). Fostering computational literacy in science classrooms. *Communications of the ACM, 57*(8), 17–21.
Wing, J. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33–35.
Wingfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25,* 68–81.
Wolfz, U., Stone, M., Pearson, K., Pulimood, S. M., & Switzer, M. (2011). Computational thinking and expository writing in the middle school. *ACM Transactions on Computing Education, 11*(2), 1–22.
Wolters, C. A., Yu, S. L., & Pintrich, P. R. (1996). The relation between goal orientation and students' motivational beliefs and self -regulated learning. *Learning and Individual Differences, 8,* 211–238.
Young, R. A., Valach, L., Paseluikho, M. A., Dover, C., Matthes, G. E., Paproski, D. L., et al. (1997). The joint action of parents and adolescents in conversation about career. *Career Development Quarterly, 46,* 72–86.