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A Case Study of a Researcher-Practitioner Partnership in Teaching STEM+C to Rural Elementary Students

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ABSTRACT

Both computer science (CS) knowledge and workforce readiness skills (e.g., creativity, communication, collaboration, and critical thinking) have equally grown in national importance to fill the growing pipeline of CS careers. Various factors have contributed to CS job shortages, which include a lack of student instruction on, engagement with, interest in and awareness of CS and careers. Rural students, an underrepresented group, lack access to CS content and pedagogies (inquiry-based instruction) that facilitate knowledge, skills, and affect towards CS. Some states are addressing the lack of CS and workforce readiness skills through new policies integrating workforce readiness skills and CS standards into formal education, starting in elementary school. The change in policy to integrate CS into elementary education fostered a researcher-practitioner partnership between researchers and three teachers. A single illustrative case study investigated how 18 contact hours of a three-unit inquiry-based integrated Science, Technology, Engineering, and Mathematics with computer science (STEM+C) curriculum augmented 34 rural fourth-grade (10 year old) students' engagement with, interests and attitudes in STEM+C and increased their knowledge of CS careers and use of workforce readiness skills. Analyses indicated significantly positive gains in interests and attitudes in science for all students, with the greatest improvement for girls. High levels of engagement were observed and self-reported for all students, but workforce readiness skills varied across the learning units. Results suggest that inquiry-based learning opportunities that integrate STEM with CS can support primary level students' interests and attitudes in STEM and foster workforce ready skills among geographically underrepresented students.

Keywords: case study, computer science, engagement, inquiry-learning, researcher-practitioner partnership, rural, STEM, STEM+C, workforce readiness skills

Introduction

Workforce statistics continue to reflect a high need in science, technology, engineering, and mathematics (STEM) jobs (US Bureau of Labor Statistics [BLS], n.d.) as they are critical to the American economy and development of innovations (National Science Board, 2015). STEM occupations are growing much faster than other occupations (Noonan, 2017); computer science (CS) jobs comprising over half of these projected jobs (Code Advocacy Coalition, n.d.). In recognition of the growing need for CS workers, states are passing policies to implement CS standards into the K-12 curriculum (Code Advocacy Coalition, n.d.; Sawchuk, 2017). In addition, states like Virginia (where the study took place) have coupled these policies with parameters to ensure students acquire *workforce readiness skills*, meaning their K-12 educational experiences foster communication, collaboration, critical thinking, and creative thinking. These attributes are also known as the 4Cs, which represent learning and innovation skills necessary for success in work and life in the 21st century (Partnership for 21st Century Learning, 2015). The first two skills of communication and collaboration relate to proficiencies in relating information and working with peers, whereas the latter skills of critical thinking and creativity describe the sophisticated thinking needed to address emergent issues and global problems (National Education Association [NEA], 2012). Other research has used the 4C paradigm in relationship to workforce readiness in adolescent literacy (Ehren & Murza, 2010), therefore, STEM subjects are a logical place for CS integration and to engage students in utilizing and practicing workforce ready skills (DeJarnette, 2012).

A 2018 report on the *State of Computer Science Education* by the Computer Science Teacher Association (CSTA) and Code.org Advocacy Coalition, stated that adoption of K-12 CS standards requires all schools to offer CS guided by policies to increase access to CS (e.g. by allowing CS to count towards core graduation requirements). In order for schools to have CS in secondary spaces, primary schools must begin integrating CS into their curricula. Schools and educators are preparing for CS policy implementations, especially in the elementary schools, where it is expected to be integrated into the current STEM curriculum, despite STEM having the least amount of instructional time (DeJarnette, 2012). Even though these policies are in place, it does not mean they will be fully supported, especially in rural areas that have less access to resources needed to teach the current curriculum (Johnson & Strange, 2007; Monk, 2007).

Since STEM learning is a broad area that embodies many subject areas and teaching and learning strategies vary (Lamb et al., 2015), it is important for the authors of the study to explicitly state the definition of STEM education in Virginia which entails 'authentic learning experiences for all students with an interdisciplinary and applied approach where all fields connect in complex relationships' (VDOE, 2017, para. 1). Lamb et al. (2015, p. 411) has suggested that this view of STEM can provide elementary teachers an opportunity to integrate more cross-curriculum learning approaches to the subject areas they are already responsible for teaching that "requires less specialization and more ability to see across areas of interaction and the resultant complexity within the STEM disciplines." However, for STEM and CS education (referred herein as *STEM+C*) to become an ordinary part of elementary instruction, teachers need support to implement curriculum that is engaging, inquiry-based, and STEM integrated within classrooms (DeJarnette, 2012). Therefore, the purpose of this research was to explore how an inquiry-based integrated STEM+C curriculum, developed within a researcher-practitioner partnership, augmented rural fourth-grade (10 years old) students' engagement with, interests and attitudes in STEM+C, as well as increased their knowledge of CS careers and use of workforce readiness skills. To establish the needs and gaps that this study addresses, we review literature on researcher-practitioner partnerships, elements of enhancing elementary students' engagement, interests, and attitudes towards STEM+C, and the improvements to workforce readiness (skills) that inquiry-based STEM+C experiences provide to primary-level learners. This review of the literature provides an understanding as to how collaborative partnerships, and the interventions they design, are actively improving American STEM education.

Researcher-Practitioner Partnerships

An approach to connect education theory to classroom practice is through higher education institution partnerships between researchers and teachers, co-designing STEM lessons (DeJarnette, 2012). Researcher-practitioner partnerships (RPPs) commit to solve practical problems, such as new instructional content, through collaboration (LeMahieu et al., 2017). Involving and supporting classroom teachers in developing new curriculum has been incredibly successful (Webb et al., 2017); and allows for avenues for research that is more useful to practitioners (Baker, 2003). Hence, the RPP was a useful avenue for conducting research on co-created classroom intervention, like integrated STEM+C learning through an elementary curriculum.

Student Engagement, Interest, and Attitudes

In tandem with employing best practices, the curriculum should be engaging for students (Ainley, 2012; The New Teacher Project [TNTP], 2018). Engagement is acknowledged as a construct difficult to both define and measure (Christenson et al., 2012), therefore, in the context of this study, engagement is defined as the degree at which a student positively or negatively attends to, or shows an interest in the completion and involvement in a specific classroom activity through constructs of behaviour, affects/emotion, and cognition. Hence, engagement is an important attribute for improving student learning (Trowler, 2010), especially when related to academic achievement from elementary school learning experiences (Ainley, 2012; TNTP, 2018). Therefore, content such as STEM+C activities, must contain specific strategies to foster engagement for elementary students such to kindle their interests in CS and STEM.

The nature of the empirical relationship between engagement and interest (Lam et al., 2012) is considered as interrelated, given that interest is often a trigger to engagement (Ainley, 2012). Interest, in this study, is defined as a motivational variable to foster desire for learning (Frenzel et al., 2010). The connection between interest and motivation is significant as research from Osborne et al. stated that "motivation offers important pointers to the kind of classroom environment and activities that might raise pupils' interest in studying school science" (2003, p. 1049). Further, these authors relate the importance of interest to fostering positive *attitudes* for science, a vital component of science education. Attitudes are an overall evaluation of stimulus objects that are influenced by affective, cognitive and behavioural information (Haddock & Maio, 2004). Ensuring that STEM+C learning experiences are interesting and engaging to students can lead to positive attitudes towards STEM (Christensen et al., 2015), even for the youngest of learners (like pre-school, see Leibham et al., 2013). In turn, early and rich STEM+C experiences may help mitigate known declines in STEM interest in middle and high school (George, 2000; Sadler et al., 2012) when students begin establishing their career beliefs in middle school (Kier et al., 2014; Skamp, 2007). Hence, developing even a nascent awareness of STEM careers is vital for student in the primary grades (Dorph et al., 2017).

Current studies suggest that if we provide students with access to STEM as early as elementary school, it not only increases their interest in pursuing STEM careers (Ball et al., 2017; littleBits, 2018; Tran, 2018), but also reduces inequalities in access and opportunities to learn STEM and develop workforce readiness skills, like problem-solving and communication (Sarama et al., 2018; Tran, 2018). As CS has an inherent technological component, it may play a unique role in engaging elementary students in STEM learning (Kurz et al., 2015) by increasing students' interests in STEM by connecting it to a curricular context (Lam et al., 2012; Li et al., 2010; littleBits, 2018). Further, STEM-based elementary interventions that employ technology can increase interests and attitudes in STEM while supporting workforce readiness skills if coupled with strong pedagogies like inquiry-based learning (Eccles & Wang, 2012; Lam et al., 2012; Li et al., 2010).

Inquiry-based Learning for Workforce Readiness Skills and Student Engagement

Inquiry-based pedagogies can also support student engagement (DeJarnette, 2012; Finn & Zimmer, 2012; Trowler, 2010) and is often implemented through group work where workforce readiness skills like collaboration and communication skills are emphasized (Tran, 2018); however, there is still a lack of frameworks that guide best practices for implementing STEM programs, even those implemented at the secondary level (Heil et al., 2013). Simply exposing students to one-day events in STEM has not provided positive results in effectively increasing positive perceptions and interest in STEM careers in the primary years (Kurz et al., 2015). However, providing integrative approaches for classroom-based STEM activities has shown significant increases in attitudes (Toma & Greca, 2017; Tran, 2018) and interest (Lamb et al., 2015), suggesting that a curriculum developed through an RPP that focuses on engaging, inquiry-based integrated STEM+C curriculum would be beneficial to primary level learners.

Importance of RPP in Enhancing American STEM Education

The National Science Foundation (2017) has recently shifted more funding to elementary STEM learning, providing greater opportunities for researching elementary STEM+C learning experiences. As a result, the growing literature on STEM+C began with research on the efficacy of short-term interventions like one-day events (Kurz et al., 2015) and classroom lessons (Ball et al., 2017), to longer-term interventions including entire learning units (Lamb et al., 2015; Li et al., 2010; Toma & Greca, 2017; Tran, 2018). Kurz et al. (2015) has suggested that STEM+C interventions have fallen short of connecting content relevancy to students and lack in use of inquiry-based learning methods. These criticisms are well taken as connecting content learning to STEM careers can provide a valuable context to learning experiences (Li et al., 2010) and technology can increase interest (Kurz et al., 2015) and mitigate geographic disparities.

While policy demands make their way into classrooms to drive instructional changes, many educational institutes will struggle especially in those that lack resources (i.e., rural schools). Rural schools often lack the expertise of content area specialists dedicated to integrate concepts effectively, as well as the expertise of someone with integrating CS and general resources (Johnson & Strange, 2007; Monk, 2007). Interventions often model those that would be difficult for rural schools to replicate, as they are often hours away from experts that are generally located in the urban and suburban areas (Kurz et al., 2015), but connecting students with professionals in the STEM and specifically CS fields is important (Li et al., 2010). Rural areas need to capitalize on technologies, such as video conferencing, to provide diverse exposures to STEM+C careers.

Models of research describe interventions that include more long-term exposures to STEM+C, but still show the need for teacher support (Guzey et al., 2016; Toma & Greca, 2017; Tran, 2018). Other models have shown that learning experiences in STEM can gain momentum in changing students' interests (Lamb et al., 2015); however, teachers need support in providing more hands-on, inquiry-based activities in mathematics and science (DeJarnette, 2012). Educators are also challenged with a lack of resources in general (Guzey et al., 2016; Kotok & Kryst, 2017; Li et al., 2010), suggesting rural, underrepresented students will fall further behind in educational experiences (Biriescu & Babaita, 2014) as STEM+C initiatives challenge educators responsible for these large populations of students (Sawchuk, 2017).

Purpose of Study

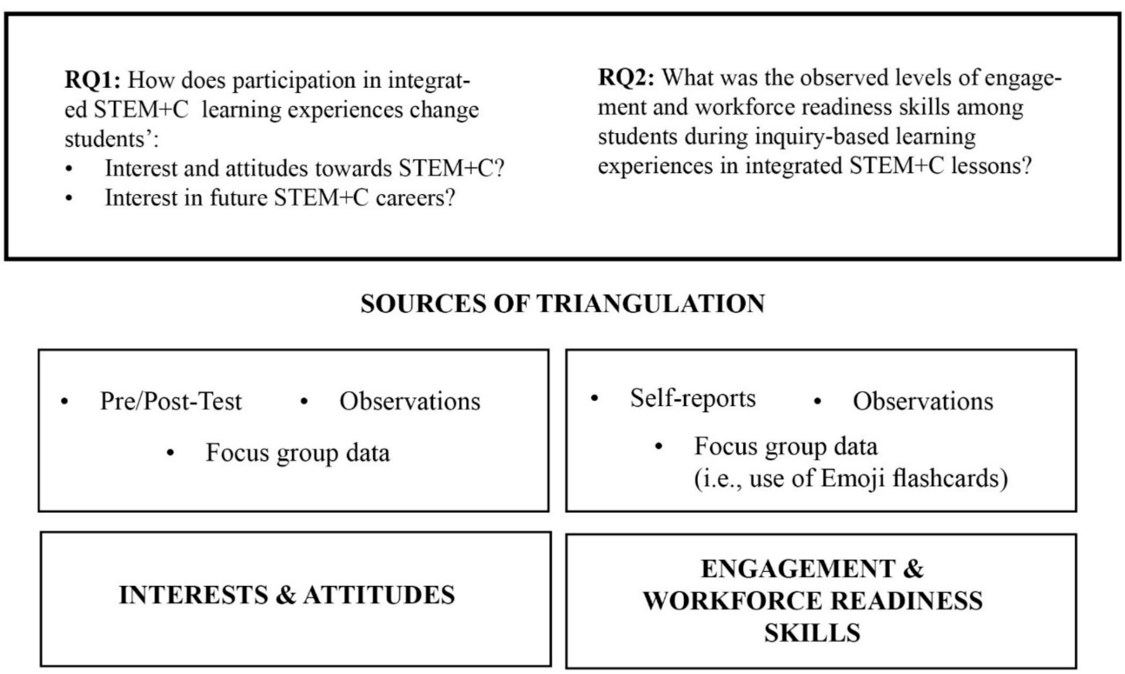
The purpose of this study was to examine how an integrated STEM+C curriculum for a primary-level audience influenced students' interests and attitudes in STEM, enhanced their knowledge of STEM careers, engagement and use of workforce readiness skills. A year-long (i.e., 18 contact hours) series of classroom-based interventions employed three central activities that emphasized use of workforce readiness skills to accomplish CS-related tasks (i.e., design/test a moving object, create sculptures with circuitry, and develop an ecosystem video game) with 34 rural fourth-grade students that were approximately 10 years of age. The questions and sub-questions that guided the research were:

1) How does participation in integrated STEM+C learning experiences change students':
    a. Interest and attitudes towards STEM+C?
    b. Interest in future STEM+C careers?
2) What was the observed levels of engagement and workforce readiness skills among students during inquiry-based learning experiences in integrated STEM+C lessons?

Methodology

The RPP was initially precipitated by requests from two teachers from a rural school who expressed concerns in new policies mandating the teaching of STEM+C. Researchers met with teachers, observed their classrooms, and provided feedback such to develop an 18-contact hour, 3-unit intervention for integrated learning experiences through inquiry-based pedagogies with a focus on STEM+C objectives. Therefore, a single illustrative case study design was selected since the unit of analysis (students) comprised of aggregate classrooms, who engaged with 3 separate units (activities) related to both the intervention (STEM+C) and constructs of interest (interest, attitudes towards STEM+C and related careers as well as engagement and use of workforce readiness skills). Multiple sources of evidence (surveys, self-reports, focus groups, observations) over a prolonged duration of time were collected for robustness (Yin, 2018). Figure 1 describes the triangulation across data sources, both qualitative and quantitative for case analysis.

Figure 1
Research Questions Aligned with Triangulated Data Sources



Thirty-four fourth graders from one rural elementary school in Central Virginia participated in the case study. The school reported that 54% of their student population for the 2017-2018 school year qualified for free and reduced lunch, indicating a majority of the school's population to be that of low socioeconomic status (SES). Students of low-SES tend to be represented less in STEM pathways (Barzanji, 2013; Niu, 2017; Xie et al., 2016), suggesting a viable sample. Therefore, the classroom intervention created and implemented within the RPP sought to facilitate engaged learning and cultivate positive interests and attitudes towards STEM+C by having under-represented fourth graders utilize workforce readiness (4Cs) skills. Data collection occurred over the course of four, small-group lessons. The lessons were part of larger learning units that included objectives for moving objects, electricity, and animal ecosystems (i.e., Data collection I, II, IIIa, and IIIb), respectively.

The first data collection occurred when students used probeware to measure friction while pushing or pulling an object designed to assist an animal to cross a busy road. As part of the process, students had to program a small robot to autonomously enter and exit the device they created. The second data collection took place during an electricity unit where students were challenged in pairs to use conductive and non-conductive playdough to create a sculpture that powered lights. Next, students had to use science terminology to verbally explain how they created their sculptures, then sequence the process of recreating their sculpture through a 'how to guide' so others could replicate. The last two data collections took place over the course of an ecosystem unit that occurred in two portions (hence data collection IIIa and IIIb) spanning over three weeks. Students were challenged to research an animal of their team's choice to be the main character of a video game they would develop. Later, students designed their game by using a combination of manipulatives and mobile devices to create the components of their animal's ecosystem (e.g., predator and prey relationships, biotic and abiotic factors).

Measurement Tools

Participants from all three fourth-grade classrooms were surveyed pre- (beginning of the school year) and post- (end of the school year) participation in the learning experiences using the validated *Student Attitudes toward STEM (S-STEM) Survey* (FI, 2012) to evaluate changes in students' interest and attitudes towards STEM, careers, and workforce readiness skills. An adapted, digital version of the tool included a section reworded from science to computer science. Graphic cues can be helpful when collecting information from young children (Chambers & Johnston, 2002; Norman, 2012), so Emojis accompanied text for the survey's 4-point Likert scale. Related graphics were also used for STEM careers questions to scaffold completion of the survey. In order to keep consented participation transparent, all fourth-grade students participated in the survey, as well as through the additional methods of data collection.

Classroom observations were conducted using the *Engagement Observation Summary* (Activation Lab, 2016), a tool used to measure observed levels of student engagement. The observation data was used to verify information collected by additional survey and focus-group data, as it has been done in other research on engagement (Fredricks & McColskey, 2012). After each observation, students completed a self-report using the *Engagement in Science* tool (Activation Lab, 2016), which was followed by a focus group to help identify emerging themes regarding students' attitudes towards STEM+C, career interests, and workforce readiness skills. A tool to better organize the focus group data collection process was created by the researchers to facilitate the collection of data. Questioning strategies that presented themselves more 'game-based' were used during the focus group to accommodate for the younger age range. For example, Emoji signs were used to help students identify and describe their levels of affective and behavioural engagement, as well as their use of 4C skills from the activity. The data collection tool and game-like strategies provided a way to listen to what students had to say about their experiences and helped understand how the quality of learning experiences could affect student engagement (Dunleavy & Milton, 2009).

Validity

Validity was strengthened by using validated instruments (i.e., S-STEM, Engagement Observations Summary, Engagement in Science self-report, and EQUIP). Prior to data collection, the Emojis used for the S-STEM Likert scale were piloted with students of the same grade level as the study's participants. The EQUIP observation tool (Marshall et al., 2009) was used to measure the overall quality and variation of inquiry-based teaching observed (per Carlone et al., 2011). While the lessons were reviewed by experts before implementation, Carlone et al. (2011) used the EQUIP tool to rate the overall quality of implementation across different classrooms with different teachers as a proactive measure. Since this tool was only used as a guide to validate the quality of inquiry of an implemented lesson, only the tool's rubric for instructional and curriculum factors were used to evaluate lessons in this research study. The method of using these factors of the EQUIP tool to evaluate the level of inquiry of a lesson has been used in other studies (Henderson-Rosser et al., 2017).

Reliability

For reliability, there was transparency in the role of the observing researcher (Zohrabi, 2013), including documentation of time spent on the intervention. Utterances from the observations were used to code for the 4Cs, whereas utterances from the focus groups primarily used open codes. The triangulation of data across sources also provided a way to expose credibility to the case study findings exposing the coherent study design while maintaining the study's aim (Hyett et al., 2014). In addition, a statistical measure, Cronbach's alpha, was run to assess the internal consistency of the sets of scale and test items (Field, 2013) for both the S-STEM and the Engagement in Science self-report. The S-STEM reported high internal consistency (i.e., above 0.7) for all sets of test items. The Engagement in Science is self-report instrument, validated for overall engagement across three constructs with two sub-factors of the scale including an affective and combined cognitive/behavioral construct of engagement. However, Cronbach's alpha suggested that only the overall and affective test items had a high reliability (greater than 0.7), whereas the combined cognitive and behaviour constructs was low (i.e. 0.53) in the study administration and thusly removed from the final analysis.

Trustworthiness

To ensure trustworthiness, steps were taken to enhance qualitative data collection, analysis and interpretation. Researchers have criticized the reliability of using observation tools to measure engagement due to a lack of experience (Fredricks & McColskey, 2012), so five hours was dedicated to piloting the Engagement Observation Summary prior to the start of data collection. The observer found using field notes during observations was a more reliable method then recording directly on the protocol; such an adoption was suggested by the developers (Activation Lab, 2018). Further, this method provided an opportunity to neatly rerecord the field notes for the additional use in using the tool's coding procedure to quantify observed levels of engagement (i.e., overall, cognitive, affective/behavioural).

To ensure reliable coding, data collection I was first double coded by two researchers, mutually agreeing upon the NEA's (2012) definition of 4C constructs. Open codes were combined for similar meanings and the remaining data were analysed by the same two researchers. To measure intercoder reliability, percent agreement was calculated between coders on all four data collections. Percent agreement was 85%, 82%, 77%, and 80% respectively. A third researcher reconciled disagreements between coders one and two for each of the 4C constructs.

Limitations

Given the tailored nature of the intervention in the RPP collaboration, external validity is a limitation as different results may arise from use of the intervention in a different geographic setting with different students (Zohrabi, 2013). However, use of theory and best practices helps to mitigate these factors. Additionally, one of the researchers played the lead role in implementing most of the learning experiences with the students since the teachers were building their own confidence about implementing lessons with new resources through small-group work; however, the benefits to the teachers own experiences of integrating effective and engaging STEM+C out weighs the potental for limitation. Another limitation is the dearth of data collected to fully understand students' connections to STEM careers. Meaning, students interacted with STEM experts related to their learning content, but the researchers did not make any formal observations during these experiences. Lastly, observations of workforce readiness skills were not normally distributed amongst the three interventions, and creativity was observed the least although the interventions provided a lot of choice in design outcomes. However, creativity is a construct that is known to be difficult to observe reliably (Katz-Buonincontro & Anderson, 2018; Michael & Wright, 1989), so it was likely undercounted. Also, since the protocol only observed one student at a time, only their utterances were recorded and coded, possibly limiting the interpretation of the interactions with peers to the researchers coding that were not physically present during the activities. We acknowledge the common limitations (i.e., generalizability, reproducibility, and research bias) of case study research (Yin, 2018), however, the use of extant theory and validated protocols, coupled with the rich information the case study yielded suggests findings warrant a valuable contribution to the field of teaching STEM+C among geographically underrepresented (rural) elementary aged students.

Results

Analyses were conducted on data collected (approximately 10 hours per class) from each of the four sessions that modelled integrated STEM+C learning experiences that included 21 observations, 12 classroom sets of self-reports, and 11 focus groups. In addition, data was used from the pre- and post- S-STEM survey from 32 consented participants, as two students had only completed the pre-test and so it was not used in the final analysis. Quantitative S-STEM analyses were conducted per the author (Friday Institute for Educational Innovation [FI], 2012), employing t-tests for construct level (interval) data, Wilcoxon signed-rank tests for item-level (ordinal) data, and chi-square analyses for comparisons with categorial data collected. Qualitative analyses of workforce readiness skills in collaboration, critical thinking, communication, and creativity (i.e., the 4Cs) were based on the NEA (2012), *Preparing 21st Century Students for a Global Society: An Educator's Guide to the 'Four Cs'*, as *a priori* codes since they provide vetted and comprehensive definitions of each of these constructs, which have been used in other research on STEM education (Hite & McIntosh, 2020). The coding process produced frequencies of the 4Cs which were counted from activity observations. Frequency counts were documented during the focus groups, when the students were asked if they had interest in any of the twelve STEM careers presented to them graphically. (These same graphics were used to scaffold learning for the S-STEM instrument.) Since the focus groups generally had three to five consented students at a time, the sample providing frequency data was not large enough but often yielded documented feedback from students. Frequency counts did help record verbal reports from students for affective and behavioural constructs of engagement, used only for triangulating data from students' self-reports, that also suggested students' high levels of engagement affirmed by the observational data.

Quantitative Results

Descriptive statistics was first used to analyse the pre- and post-test data for attitudes by subject area constructs of the S-STEM survey and parsed by gender (Table 1). Next, a paired t-test was used to examine STEM attitudes by subject area constructs (i.e., aggregated, numeric data) between survey administrations finding a significant positive increase in females' attitudes from pre- (M = 3.97, SD = 0.38) to post-test (M = 4.35, SD = 0.30) in mathematics and pre- (M = 3.57, SD = 0.35) and post-test (M = 4.05, SD = 0.30) attitudes in science. When the data from males and females were bounded, science attitudes from pre- (M = 3.49, SD = 0.42) to post-test (M = 3.94, SD = 0.32) evidenced a significant increase.

Table 1
Attitudes by Construct Averages Between S-STEM Survey Administrations

Construct	Number of Items	Pre-Administration of S-STEM Average			Post-Administration of S-STEM Average		
Attitudes about:		Total (*N*=32)	Females (*N*=19)	Males (*N*=13)	Total (*N*=32)	Females (*N*=19)	Males (*N*=13)
Science	9	3.49	3.57	3.37	3.94	4.05	3.77
Mathematics	8	4.10	3.97	4.29	4.40	4.35	4.47
Computer Science	9	3.34	3.32	3.38	3.68	3.75	3.57
Technology and Engineering	9	3.99	3.92	4.09	4.11	4.09	4.13
21st Century Learning	11	4.35	4.53	4.09	4.39	4.54	4.18

Note. Responses based on a 5-point Likert scale, Strongly Agree (5) to Strongly Disagree (1).

The Wilcoxon signed-rank test was employed to compare pre- and post-test data, at the item-level (i.e., ordinal, Likert data), from the S-STEM survey. Four question items showed positive significance including choosing a career in science from pre- (Mdn = 3.00) to post-test (Mdn = 3.00), T = 176, p = .031, r = 0.38, knowing science will help earn money when they are older pre- (Mdn = 3.00) to post-test (Mdn = 4.00), T = 202, p = .013, r =0.44, needing to understand science for a job when they are older pre- (Mdn = 4.00) to post-test (Mdn = 4.00), T = 157, p = .012, r =0.45, and thinking computer science is not so hard to understand pre- (Mdn = 3.00) to post-test (Mdn = 4.00), T =236, p = .045, r = 0.35.

S-STEM results further suggested that students' perceptions increased from pre- to post-test of their mathematics (75% to 84%) and science (59% to 75%) performance. Additionally, there were gains in their knowledge of STEM+C careers with the largest gains in girls' knowledge of scientists and computer scientists (Table 2). An expanded section of the survey asked students to identify sources of information in which students' gained knowledge of STEM+C professionals including school and/or textbooks, magazines and/or books, home and/or family, television, and internet or social media. Students reported gains in knowing STEM+C professionals from school and/or textbooks and internet or social media. For example, at the beginning of the school year students reported 6% of their knowledge of computer scientists came from school and 16% from internet related sources. At the end of the year, 41% came from school and 37% came from the internet. Similar gains in both these sources of information were found in all subject domains, except mathematics. The post-test data showed only 9% of students knew of a mathematics career from school and 28% from the internet.

Table 2

Knowledge of STEM Professionals by Averages Between S-STEM Survey Administrations

Type of STEM Career	Pre-Administration of S-STEM			Post-Administration of S-STEM		
	Total (*N*=32)	Females (*N*=19)	Males (*N*=13)	Total (*N*=32)	Females (*N*=19)	Males (*N*=13)
Scientists	17 (53%)	9	8	26 (81%)	16	10
Engineers	21 (66%)	9	12	26 (81%)	15	11
Mathematicians	13 (41%)	7	6	16 (50%)	11	5
Technologists	18 (56%)	10	8	25 (78%)	16	9
Computer Scientists	16 (50%)	7	9	26 (81%)	16	10

Note. Responses were a Binary choice, Yes (1) or No (0), which represents who they knew.

After each activity that was observed, the Engagement in Science self-report was given to the students. The survey data was analysed with descriptive statistics and found that the students reported very high to high levels of affective and overall engagement (i.e., affective, cognitive/behavioral) during the four data collections (Table 3). Notably, the lessons across all the classrooms were evaluated for levels of inquiry using the EQUIP tool, and results suggested that all the activities were proficient or exemplar models of inquiry-based learning.

Table 3

Students' Self-Reports of Engagement and Affect, including Overall Averages

Activity	N-Size	Affective Construct Score	SD	Overall Engagement Score	SD
Data Collection I	31	1.68	0.76	1.65	0.85
Data Collection II	29	1.45	0.56	1.49	0.68
Data Collection IIIa	32	1.26	0.42	1.38	0.74
Data Collection IIIb	24	1.24	0.46	1.36	0.73

Note. Responses based on a 4-point Likert Scale, YES! (1) to NO! (4).
The self-report is validated to make inferences from two sub-factors of the scale (i.e., affective score or a behavioral/cognitive score), but a low reliability for a behavioral/cognitive score merited it being eliminated from the findings. The survey is also validated to make inferences regarding the overall engagement (i.e., a combination of affective, behavioral, and cognitive engagement).

Qualitative Results

The observation protocol, supplemented by researcher field notes, provided summative values on constructs related to engagement. In addition, a combination of the observation and focus group utterances were coded by the researchers for workforce readiness skills (i.e., the 4Cs) and open codes were developed and merged for further analysis. The open codes documented utterances that illustrated a transfer of knowledge/connection, personal interest and/or ability, but were primarily found in the coding of the focus group data. Workforce readiness skills were analysed by using the frequency counts of utterances coded for the 4Cs for each of the four activities. In each section, the specific skill is denoted in braces for the reader. Chi-square analyses of independence were run to examine relationships between the activities and the frequencies of observed skills. Significant differences were found, X^2 (1, N=280) = 21.85, p = .009, meaning the skills were not observed consistently across the four activities. Data collection I had the most observed actions related to students observed use of the 4Cs (N = 88), followed by IIIb (n = 72), II (n = 68), and IIIa (n = 52). Data collection I had more observations of critical thinking (n = 41) and collaboration (n = 22) observed as compared to communication (n = 19) and creativity (n = 6). For example, Sarah [pseudonym] was observed critically thinking through collaboration with her group as, "well, then we have to start her [robot] and go through here," referring to how to plan the robot's path through the maze. Students in data collection I were tasked with ways to think critically; Jane described their skill use in the focus group as:

> we were going to discuss with the group {collaboration} and then the car was going bad and now we had to like scratch, um, what we were first working on. We're working on, we have to sketch it because we have to go across the road and not under it {critical thinking}.

Data collection II, had more observations of critical thinking (n = 29) and communication (n = 23), while collaboration (n = 11) and creativity (n = 5) were less observed. Lee was determining the type of circuit by thinking aloud in his group {communication} that it was "parallel because if we take a light out (takes light out) {critical thinking}, it still works!" In this activity communication was key, Julie admitted in the focus group when communication broke down, "…it was hard working with somebody that was trying to kind of do it all…I tried to add designs, but she, um, just covered them with playdough." Data collection IIIa, had more observations of collaboration (n = 19) and critical thinking (n = 13) and less of communication (n = 11) and creativity (n = 9). Students actively collaborated in the co-construction process, Sean exclaimed, "we are making the guppy's home, it's a coral reef!" This sentiment was amplified by Carol in the focus group when they said, "Yeah, we all worked in the group to make the character. We all figured out things together {critical thinking} and we didn't leave anybody out {collaboration}." Data collection IIIb, had more observations of critical thinking (n = 26) and communication (n = 22) and similar observations of collaboration (n = 11) and creativity (n = 13). Interestingly, by this final data collection point, students were more able to communicate their ideas and identify problems productively. Joyce during the activity identified that, "we need to add the seaweed," and Heather raised their concerns in stating, "that's not white, it's orange." Improved communication provided avenues for troubleshooting, as Morgan shared in the focus group, "when we figured out Cactus Boy could not be our main character and go back and make it snake and re-plan {critical thinking}." Altogether, reports of critical thinking were most observed (n = 109), followed by communication (n = 75), collaboration (n = 63) and creativity (n = 33).

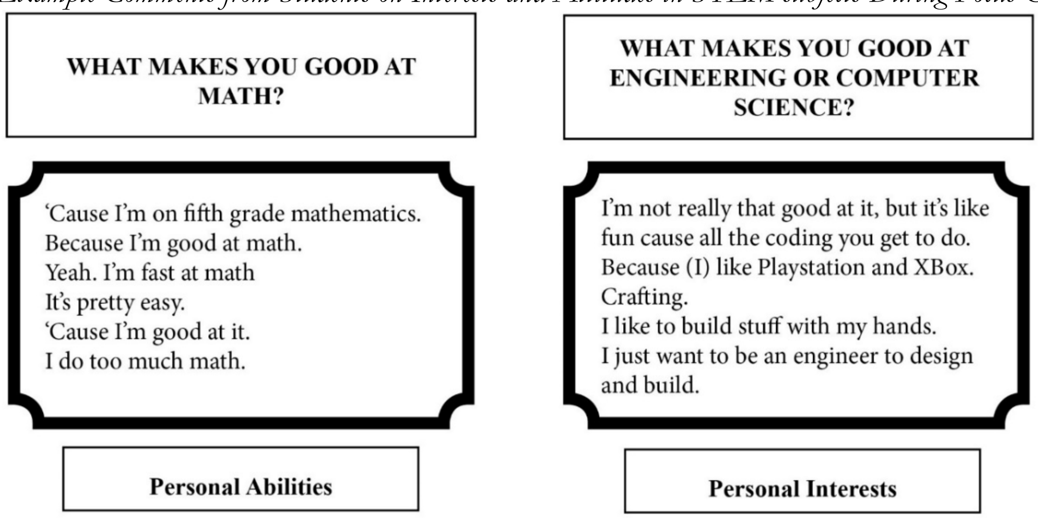
Case Analysis and Discussion

Overall, the study aimed to understand how integrated STEM+C lessons, developed through a RPP, could augment fourth grade students' attitudes and interests towards STEM+C. Case results suggest significant positive gains in interests and attitudes in science for all students, with the greatest (significant) benefit for girls in both science and mathematics. This finding supports a study by Grover et al. (2014) who found students' experiences in CS helped them to not only understand CS, but also develop their appreciation for its applicability across disciplinary domains. Findings also support existing research that suggests integrative STEM learning experiences can positively support students' attitudes (Toma & Greca, 2017; Tran, 2018) and interests (Lamb et al., 2015) in specific areas within STEM.

Further, students reported improved perceptions of their abilities to perform in science and mathematics. Focus group data suggested that students often equated their personal ability for math to their high performance in mathematics, however, when it came to engineering or CS, their perceptions relied more heavily on personal interests than innate ability (see Figure 2). Comments pertaining to the other subject areas were similar, meaning students balanced perceptions of their abilities in the subject with their interest in the subject. These findings extend current thinking to how students' evaluations through formal assessment (e.g., grades) become conceptualized by students as the ability to learning facts and formulas, as opposed to their perceptions of inherent ability (Haimovitz & Dweck, 2017). This study indicates this ability-interest negotiation occurs at very young ages and is important considering perceptions of ability helps to forge one's personal interest (in science). Further, these findings support the need for educators to endorse a deeper learning process within science as well as other subject areas.

Figure 2

Example Comments from Students on Interests and Attitudes in STEM subjects During Focus Groups



Much of the S-STEM data for STEM career aspirations had a ceiling effect from pre- to post-administrations; however, student awareness increased in the different STEM-based careers. The greatest increase was in knowledge of professionals in STEM+C careers, especially for sampled girls. Meaning, knowledge of professionals in CS doubled from pre- to post-intervention for girls in every career except mathematics. Students reported they garnered their STEM career knowledge largely through school and/or textbooks and the internet or social media, suggesting the students were 'seeing' more STEM career experts both in- and out-of-school. Greater exposure to STEM careers affirms related research that also found career knowledge growth among middle-grades students when watching STEM career videos (Kier et al., 2014). Findings suggest such experiences to generate career awareness are beneficial for elementary learners, too.

Workforce ready skills, categorized by the 4Cs, were observed throughout the intervention, but were not equally among the four activities. Communication and collaboration were most evidenced with creativity as the lowest observed construct across all of the activities. First, there were over 30 more observed actions between data collection I and IIIa. Data collection I, a challenge that involved using probeware to measure friction in conjunction with learning a new tool to code and help simulate the outcomes of a designed prototype had the greatest number of observations that included critical thinking and collaboration, suggesting these skills were used more frequently to complete the inquiry-based learning experience that incorporated many new learning experiences merging together into one learning experience. Data collection II, a paired student activity where students got to create their own object out of conductive playdough, had more observations of critical thinking and communication than expected, suggesting that decreasing the number of students to collaborate can increase the communication in the group to problem-solve. These specific findings affirm current research that shows workforce readiness skills can be supported through inquiry-based learning activities (Tran, 2018). Further, findings suggest consideration of cooperative groupings of students (e.g., size) is vital to maximize use of those skills.

Data collection IIIa and IIIb also had interesting results, as they varied in observations across the 4Cs although the students were engaged in the same learning project. In the third learning unit of the intervention, students researched and developed a plan to create a video game to illustrate an animal's ecosystem. In both data collections for their project, students were actively building their video games through the use of manipulatives to create their main character and the interactions the organism had with its ecosystem through adding assets and animations to their game scenes to include items like sources of food, shelter, and water. However, data collection IIIa observations suggested collaboration was observed the most and for data collection IIIb, critical thinking was observed the most, which may have to do with the idea that while the students were actively iterating their video game designs, more troubleshooting (e.g., debugging program glitches) occurred to make the products play better for the audience as time progressed in the project.

Creativity lacked the most in overall observed occurrences across all of the learning activities. While all of the activities provided constraints, they also provided student choice in how they wanted to creatively illustrate their learning outcomes. For instance, data collection II had the least number of occurrences observed and coded for creativity, yet the activity gave students the least amount of constraints to create a product. Data collection IIIa and IIIb had the most occurrences of creativity, suggesting the activity fostered an environment for the students to be creative, but the overall lower frequency of observed creativity across all the learning experiences suggest that it was harder to observe (Katz-Buonincontro & Anderson, 2018). Regardless, this suggests teachers should leverage explicit avenues for students to engage in creativity activities, so they can be used, grown, and observed.

In regard to engagement, throughout the intervention students reported high to very high levels of engagement in their self-reporting and focus group data (see Table 3). The affective engagement and overall engagement gradually increased with every activity observed, including the last two activities which had the same learning objectives, but took a longer period of time to implement. Fewer observations initially may be attributed to the inexperience of sampled students with small group, inquiry-based learning, which grew over time. As the intervention progressed, students began to engage more in the activities as they got accustomed to active participation, extending current research suggesting that inquiry-based learning activities need to also be engaging to positively support STEM learning opportunities (DeJarnette, 2012; Finn & Zimmer, 2012; Trowler, 2010). This indicates that younger students will need scaffolding for STEM+C activities that task them with employing 4C-based skills.

Conclusion

Results suggest among the 34 underrepresented, rural fourth students that had participated in the three RPP designed inquiry-based learning modules integrating STEM+C, sampled students' interests, attitudes and workforce readiness skills (within the 4Cs) had improved. The intervention also proved to be positively engaging to students. One of the largest impacts appear to be how the students were able to connect their context of learning and relate it to STEM career opportunities. While this study provides an opportunity to examine an intervention over a year-long period, it still leaves a gap in the number of longitudinal studies that measure student engagement (Reschly & Christenson, 2012). Further research needs to be designed to measure changes in students' interests and attitudes in STEM+C and STEM+C careers from elementary to secondary education, where students begin to choose courses for their career pathways, after participating in STEM+C interventions.

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