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App Development in an Urban After-School Computing Program: A Case Study with Design Implications

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Abstract

This mixed methods case study presents the experience of a group of middle school students in a year-long, after-school computing programme in a large, inner-city school district in the southeastern United States. The purpose of this research is to explore informal educational strategies that are conducive at giving underrepresented minority youth access to information and communication technology tools and content. Results indicate that hands-on support from mentors, peer collaboration, and options for customising work and creating unique projects contributed positively to the student experience in the programme. This study suggests giving students more creative freedom, adequate scaffolding and the option for peer collaboration when working in informal learning environments. Results are specific to the context of the one school in which this pilot study was conducted, though the findings confirm the research of others in this area. Data sources included a perceptions survey, participant interviews and researcher observations.

Keywords: Computer Science Education, Broadening Participation, After-School, Case Study, Information and Communications Technology (ICT)

It has been widely reported that students who are from populations that are traditionally underrepresented in information and communications technology (ICT) tend to not seek education and employment in ICT-related fields in part because they have less access to relevant resources and, thus, fewer relevant educational experiences (Code.org, 2018). This condition, which can contribute to workforce shortages and sociocultural inequity, has gained the attention of government organisations, non-profits, funding agencies and philanthropic foundations, many of whom who have put out calls to help try and solve this problem (National Research Council, 2011; National Science Foundation, n.d.; The White House, 2016). In turn, a growing body of research and development has been focused on broadening participation in science, technology, engineering and mathematics (STEM) and ICT (Aspray, 2016; Gardner-McCune & Jimenez, 2017; Goode, 2008; Lachney, 2018; Ryoo et al., 2013).

One area within this body of work involves providing quality experiences for traditionally underrepresented youth via informal learning environments such as museums, makerspaces, computer labs, community centres and school-based after-school programmes (Barron et al., 2014; Kafai et al., 2009; Mouza et al., 2016). Informal learning environments have been reported in the literature as well suited for bridging gaps in access to STEM/ICT education in part because these programmes can afford students who may not have such opportunities during the school day, the time and freedom to learn how to be producers rather than consumers of digital technologies (Ericson & McKlin, 2012; Maloney et al., 2008; Scott et al., 2015). In these environments, students can develop new skills and be exposed to new scholastic possibilities, but programmes should also try to match a curriculum to the interests of the participants and what they culturally relate to out of school while also demonstrating broader application beyond the classroom in order to inspire students to learn and create (Ladson-Billings, 2014).

App building for smartphones is a growing area for research, particularly as a means for motivating learning and introducing students to fundamental programming concepts that they will experience in their broader computer science education (Rahman, 2018; Tsai, 2019; Wagner et al., 2013). App building serves as a springboard for engaging students in programming mainly due to the popularity of smartphones and the ubiquitous presence of apps in people's lives. According to a 2018 survey conducted by the Pew Research Center, over 90% of American teens polled own or have access to a smartphone at home, regardless of ethnicity (black, white or Hispanic) and socioeconomic status. Furthermore, the survey found that 45% of teens describe being on the internet 'almost constantly', while another 44% use it 'several times a day' (Anderson & Jiang, 2018). The utility of being able to create apps for their own phones becomes self-evident since students and most of their peers would be their own target audience with the potential of reaching people across the world should they choose to publish their work.

Helping young students progress from solely being users of apps they download from their favourite online stores to app producers can be mediated through age-appropriate learning environments. Using a visual programming language (VPL) is one potentially effective way to introduce programming to novices because VPLs use a graphical user interface in which users connect blocks of code like puzzle pieces in place of manually typing out long strings of code. Furthermore, the blocks of code are typically colour coordinated and differ in shape to help visually demonstrate the relationships of the strings of code and coordinate their construction (Tsai, 2019). Arguably, the biggest advantage of using a VPL is that it allows users to focus on the logic of their programs rather than the syntax, which can help students quickly get results that they can test and debug through an emulator or, oftentimes, directly on a phone (Rahman, 2018). By design, VPLs are meant to speed up adaption of programming by making it more concrete and less abstract, allowing for more direct manipulation of objects on the screen, making relationships visually explicit (through colour coding, shape of blocks and how blocks are clustered) and giving immediate feedback – such as when users test their apps as they work to see the effects of adding new code and making edits (Burnett, 1999). With many visual programming languages being commercially available and some, like MIT's App Inventor, even being hosted and accessible for free online, it can be very advantageous to include a VPL as a platform through which students can build their own apps as they learn about computing.

This article answers a call by Mouza et al. (2016) that, 'future research should examine the benefits of CS after-school programs in more diverse contexts, in terms of both gender and ethnicity' (p. 99). This study presents a case embedded in an urban after-school programme in the southeastern United States that was comprised of largely African American middle school-aged girls and boys. The study was guided by the following question: What were the experiences of a group of middle school students in an urban, after-school computing programme, and how can their experiences help us inform future instructional designs? Specifically, how did elements of the programme and its environment appear to affect students' engagement and participation?

Method

Given the naturalistic setting and the descriptive nature of our guiding research question, the authors employed an exploratory case study design that included multiple and mixed data sources in order to give a rich description of the case. All data were collected and analysed concurrently (Creswell, 2003, 2007). As the research contained multiple units of analysis (i.e. the pilot programme as a whole as well as individual student participants), the researchers used an embedded case study model (Scholz & Tietje, 2002).

Context

The case study presented here was part of a larger, three-year, grant-funded project that included the creation, implementation and evaluation of an after-school computing programme for middle school youth at 10 middle school sites in a large, inner-city school system in the southeastern United States. This study reported here was part of a pilot of the aforementioned programme that was conducted in one of the middle school sites.

The intervention involved participants working on computer science activities that were centred around using MIT's App Inventor, a low-floor, high-ceiling (Resnick et al., 2009, p. 63) web application that allows novice computer programmers to develop a wide range of Android applications using a block-based interface. Users of App Inventor start creating apps by adding various components (like buttons, text labels, image holders and sound players) to their design screen, uploading their own media (photos, MP3s, videos etc.) and then programming the components to react to user inputs and other procedures by assembling blocks of pre-written and customised code that guides the app in all its interactions. Apps created in this afterschool programme can be as basic as triggering media after pushing a button on a phone's screen to as complicated as a fully interactive game complete with sound effects.

Activity sessions were held twice a week after school, for approximately 60 minutes per meeting in the school media centre. Activity design included an introduction to the curriculum, followed by direct instruction on how to use block-based coding to create apps that led to gradually less scaffolded activities. The direct instruction activities, called *cookbooks*, included detailed information on the basics of App Inventor and step-by-step directions on how to create pre-designed apps (Kirschner et al., 2006). The less guided activities, called do-it-yourself/DIYs, were designed to allow students room for problem solving, growth and self-expression (Brennan & Resnick, 2012; Guzdial, 2009; Kafai & Burke, 2014), with some activities geared towards connecting participants' app-building experience with relevant, tangible and, when possible, socially responsible themes (Scott et al., 2015). Activities were presented to participants in a progression of gradually increased difficulty and reduced scaffolding, although they did have the opportunity to choose activities out of sequence. The introductory activities followed a narrative of working together in a tech startup, and it involved an introduction to the curriculum and supporting materials, directions on how to progress through the curriculum, creating a tech startup team and brainstorming ideas for apps.

The instructional design was intended to involve two stages with each stage lasting approximately one semester. Stage one introduced students to the curriculum and to building mobile apps using App Inventor during the fall. Stage two involved allowing students who returned from the fall (n = 7) the opportunity to apply their knowledge and skills to a group project, which would focus on addressing an issue relevant to the students and their community (Scott et al., 2015). The group project could be submitted to an external technology competition. So, the ultimate plan was for students first to become familiar enough with the platform that they could then work in teams and create a unique project of their own design. Unfortunately, attrition, mostly due to competing extra- curricular activities such as sports, dance and mandatory tutoring, affected this aspect of the intervention despite participants expressing their motivation to submit projects. New students that joined in the spring (n = 12) worked through the same progression as those who had first attended in fall. Attendance in the spring semester (n = 19) was lower than in the fall semester (n = 31).

The early modules included mostly cookbook activities with a few DIYs that involved remixing the pre-designed apps. These activities were subdivided into smaller, manageable tasks for which students could earn ‘experience coins’ for completion. Collecting experience coins allowed students to share their successes with others as they received badges that highlighted a skill they demonstrated (like coding or problem solving), and the coins could be cashed in to facilitators for prizes such as school supplies or media assets for their apps.

Student progression through all activities as well as classroom management were led by a group of adult facilitators who included the school media specialist, a science teacher from the same school who received some training on the curriculum, three doctoral-level graduate assistants who had expertise in instructional design, technology and classroom teaching, and one masters-level graduate student in educational psychology. Facilitators were African American along with one white graduate research assistant, and they were compensated through either the grant sponsor or the after-school programme. None of the facilitators had expertise in computer science.

Data Sources

Multiple and mixed data sources informed this study. These included: pre- and post-test surveys of participants' perceptions of STEM/ICT and related careers, fieldnotes and participant interviews. We also tracked attendance, the number of activities on which students worked and the number of experience coins that students collected.

Perceptions Questionnaire

In order to better understand student perceptions of their progress in the programme and of ICT in general, the researchers developed an online questionnaire called ICT/Twenty-First Century Skills Questionnaire (ICT/21Q; Cohen et al., 2017). The ICT/21Q presents students with a list of 12 twenty- first century skills commonly cited in the literature. It then asks participants to self-report perceived abilities related to these skills. Students completed this instrument at the beginning and end of the fall term. See Appendix A for a summary of participant results on the ICT/21Q. The ICT/21Q data shows how the students' perceptions of their ability to use different skillsets change from pre-test to post-test, which is important as confidence is often cited as a predictor for continued participation (Andersen & Ward, 2014; Wang, 2013). However, the

ICT/21Q results alone cannot account for persistence and attrition results since many variables affected participation, but the data can provide additional insights on the topic.

Fieldnotes

One or more researchers recorded fieldnotes, either contemporaneously or immediately following each meeting. Participant observers focused on students' interactions with the material, the technology, the instructors and each other. Fieldnotes were created from observations of all students who participated in the programme.

Interviews

Open-ended interviews were conducted face-to-face with willing participants, with answers entered into an online survey by the researcher during the process. Each interview started with three questions that addressed: (a) students' experience in the after-school programme and the computing programme more specifically, (b) what they enjoyed, and (c) what they might like to see changed.

Data Analysis

Qualitative data, including fieldnotes, answers to open-ended questions on surveys, and interviews, was compiled into the NVivo qualitative analysis software package and analysed using a constant comparative approach (Glaser & Strauss, 2017). Two researchers with expertise in instructional design and technology and K–12 education were responsible for reading the entire corpus of data. One of the researchers first read through the data and began with open coding before the two discussed the initial findings and created a codebook. Following discussions and some negotiation, the two researchers re-examined the corpus to focus on specific themes that had emerged from codes produced in the first round of analysis. A third researcher was then invited to assist with interpretation of the data and related themes. Data from surveys was pulled from online forms and stored in spreadsheets on a password-protected server.

Data analysis for the ICT/21Q included the calculation of descriptive statistics in the SPSS statistical software. These results were used to enhance qualitative findings.

Results

This section is divided into two parts. We will begin by providing descriptions, using mixed data sources, of each of the nine students embedded within the case. We then attempt to provide the entire case based on themes that emerged from qualitative data analysis.

The Participants

While a total of 19 boys and 24 girls agreed to participate in some part of the pilot at some point during the given school year, following data collection, the researchers selected nine of these participants as the embedded focus of this case study. This choice of nine participants was made in part due to the unpredictable patterns of attendance during both semesters, which created substantial gaps in our data collection efforts for the entire group. This was also done in order to present the richest description possible of the student experience in the programme. Criteria for participant selection included: (a) having attended sessions during the fall, (b) having attended at least five 60-minute sessions, (c) having worked on at least two activities, and (d) having completed at least two data collection points in addition to the observation data. See Table 1 for participant profiles.

[TABLE 1 HERE]

Aidra

Aidra, an eighth-grader, was an outgoing student who enjoyed being the group leader for one of the larger social groups in the programme. She attended 15 sessions, completed five apps and collected 14 experience coins. Aidra continued to participate in the spring because her first exposure to it 'was, like, really good, and I just think it's a nice thing to do, since it's kind of heading towards what I want my career to be, which is like animation and doing game art'. Aidra reported that her technology skills increased during the programme on the ICT/21Q items 'Understand and use technology systems', 'Understand and use technology applications' and 'Write code' over the course of the first semester. In addition, Aidra indicated that she wished the programme would be 'more competitive', and so she worked on a group project in the spring for the science fair. Unfortunately, in the fall, Aidra reported a decrease in her ability to 'Be informationally literate', 'Use digital tools for research' and 'Design systematically'. While it is difficult to pinpoint why she scored lower in these areas, these skills could have been strongly reinforced with prolonged participation in the group project as it relied more heavily on these skills than the cookbook activities. Her interest in working on DIY activities and the group project demonstrates that she has skill in these areas and survey results in the spring may have shown an increase in her own rankings.

Eric

Eric attended 14 days, completed seven apps and collected nine experience coins. Eric enjoyed working with Aidra and similarly expressed that he would like to become a video game developer, which seemed to motivate him to persist. When asked why he returned to the programme after the first semester, he replied,

I participate in [the programme] because I want to be a video game designer, and creating apps will help me achieve high in that direction. I want to keep doing game design in high school, so it will be a good experience.

Eric found the app-building curriculum to be 'pretty cool'. Although he rated his skills at the lowest level on the ICT 21Q for the pre-test (which could be due to his not attending to the prompts), he rated his skills at the 4 and 5 (out of 5) point levels on each skill at the post-test, with the exceptions of 'Write code' and 'Design systematically', on which he again rated himself at the lowest level.

Donella

Donella was an eighth-grader who did not attend many sessions (*n* = 5) because of mandatory attendance required for her after-school dance group, though she enjoyed the programme when she was able to attend. She worked on five apps and redeemed one experience coin, making significant progress on her activities. Donella indicated that a main reason for attending was that her friends were there: 'Well first my friends they recommended it to me and I've already had some experience with making apps so I thought it would be interesting.' Like Aidra, she also wished the programme was more competitive, and she teamed with Aidra and Eric briefly to work on the group competition. She generally rated her twenty-first century skills at the 4 and 5 levels on both the pre- test and post-test, with the only real departure being her ratings on the 'Design systematically' item, which dropped from a 3 to a 1. This score is hard to qualify since Donella only worked on one cookbook app during the fall semester and did not really have time to work on a DIY project. Her score might reflect difficulty in getting started with App Inventor and the first cookbook in the fall, but she accomplished much more in a short period of time in the spring.

Alan and Spike

Alan and Spike were eighth-grade athletes who worked together very closely. Alan attended five days and completed three apps (skipping experience coins), while Spike attended six days, completed three apps and redeemed one coin. Occasionally collaborating with Aidra's group, each stated that he liked to attend the programme when friends were there. While Alan and Spike did work on some of the cookbook activities, they spent a large part of their time working on the concept for what they called an endangered species app. Alan reported increases in all of the skills included in the ICT/21Q, except for one (i.e. 'Use technology to work in teams') which did not change, and one which decreased (i.e. 'Understand and use technology applications'). The reason for the decrease is unclear, but it might indicate uncertainty with the App Inventor platform or some question of his ability to build apps in the fall. Spike only took the ICT/21Q post-test but reported high efficacy on each item, rating his skills at either a 4 or 5 level with the exception of 'Be creative', on which he gave himself a 3.

Javier

Javier was a sixth-grader who attended the most sessions across both semesters (n = 17) and completed the most work (eight apps and 10 experience coins). When asked at the end of fall about his favourite part of the app-building programme, Javier stated, 'all of it'. His positivity towards the programme persisted throughout, declaring during the spring exit interview that 'The whole thing was good. It was a good experience.' Javier enjoyed working with facilitators in order to work through problems, customise/remix his apps and show off his work, and he even worked from home and found tutorials on YouTube if the cookbooks frustrated him. Though missing the pre-test, he rated his abilities in the 4 and 5 levels in the post-test with the surprising exception of 'Write code', on which he rated his ability as a 2. Javier did question his ability to build apps in December, pointing out that he was helped by a facilitator, but we pointed out that he completed many apps without help (some at home alone) and that he is also resourceful in his ability to find information online and consult with facilitators, which is very commendable.

Kettie

Kettie was a shy sixth-grader who attended frequently in the fall (n = 8), completed three apps and collected 18 coins. Her initial partner in the programme ended up having to leave the after-school programme in order to focus more on her grades. After her friend left, Kettie mostly worked alone, which may have affected her attendance. Kettie mentioned at the end of the fall semester that she enjoyed the app-building programme, but she also indicated that she needed to focus more on her role in the dance team in the spring semester, stating that 'Competition season is coming up and we had to practice every moment we got.' During the same interview, Kettie expressed her desire to make her own custom apps 'out of my very own ideas'. At the end of the fall semester, she reported an increase in her coding ability, rating herself a 5 at the post-test (from a 2 during the pre-test).

Milissent

Milissent (sixth grade) attended twice in the fall and three times in the spring ($n = 5$), completing three app-building activities only in the spring semester though working on preliminary activities (i.e. surveys, website exploration etc.) in the fall and collecting eight coins. Milissent had to constantly change activity partners because she and her partners were rarely present at the same time. However, she mentioned that the programme activities were fun at the end of each semester. Milissent indicated the lowest level of ability in coding at the pre-test and post-test, though she knew enough about coding to express a preference for another block-based coding environment over App Inventor. Her decreases in scores from the fall pre-test to the post-test is hard to explain since her attendance was low and the bulk of her app engagement was in the spring.

Simon

Simon, a sixth-grader, was friends with Javier, which was one reason for his joining the computing programme. Simon attended 11 days, created four apps and collected 10 coins. During an interview, Simon expressed interest in learning coding and app development as well as playing football, his other favourite activity, since both skill sets had the potential to lead to lucrative careers. Simon only attended the fall session because of football and baseball practice in the spring: 'Both are really fun, but the . . . you can make your own app and maybe make money off of it, but you can do the same thing with football.' Simon also suggested that we talk more about career opportunities in app development and 'how much money can we make if we attend . . . ' Simon gave himself the highest rating on 9 of the 12 skills on the pre-test and on all the post-test items.

Thematic case narrative

Overarching themes that emerged from qualitative data analysis included: (a) support from the learning environment, (b) working with peers, and (c) authorship, purpose and agency. While we will present these themes separately, it is important to note that they occurred in a fluid and interrelated fashion within the case being presented here.

Support from the learning environment

In this study, support from the learning environment included paper-based, digital and instructor/ mentor support. Students took advantage of these support mechanisms to different degrees, ranging from students who needed support only to get started (floor), to others who required advanced technical support to execute work beyond that which the pre-designed curriculum could accomplish (ceiling). Most participants required extra support early in the programme before they became comfortable with using App Inventor, requiring less attention thereafter. This was in keeping with the strategy of gradually removing scaffolding, which had been an integral part of the curriculum design and implementation.

For instance, Donella started the programme late in the fall semester and needed help getting through the first app activity. She was able to do this by combining support from Aidra and Eric while occasionally asking facilitators for help. On her first day back in the spring, Donella was able to work on two app activities entirely on her own, only asking for help in finding where additional activities were stored online.

Some students, like Javier, leveraged the presence of adult facilitators to extend their work beyond the curriculum. His requests for support tended to come after completing an app project as he liked to customise the majority of his apps due to dissatisfaction with the aesthetics: ‘they don’t look that exciting,’ he stated during an interview. As a result, Javier either made additional visual components or searched for some online. In these instances, some of his requests for adult support were for the purpose of idea generation, feedback and finding kid-friendly repositories for public domain graphics and add-ons. For example, he liked the idea of adding sound effects to his game, Mole Mash, so he and a graduate assistant worked together using audio-editing software to create MP3s. Beyond design changes, Javier also creatively remixed some of his old code to add additional features to some of his apps. For example, he worked with a facilitator to add text-to-speech coding to an app that displayed randomised messages so that readers could hear narration while they read along with the text. This successful remixing was one catalyst that encouraged his customisation efforts. In these cases, the support of the facilitators was essential in facilitating the execution of his ideas.

Directions in the guided activities and working with facilitators was demonstrably beneficial for our students. Younger students may not typically be used to learning outside of a teacher-centred context, so a degree of in-person scaffolding should be anticipated at the start. Some students may opt to work with peers or figure things out on their own once they reach a certain comfort level.

Working with peers

Informed by the literature on the positive effects of group work and peer support in STEM learning environments, a second integral part of the programme had to do with encouraging collaboration (Ericson & McKlin, 2012; Palmer et al., 2011). At the beginning of the programme, participants were given the opportunity to self-select into groups to form startup companies. Group work in the pilot study presented here cannot conclusively be tied into students gaining a deeper appreciation for the subject matter or persisting in the programme, though several students were motivated to give the programme a try thanks to the participation of their peers. In addition, students were often observed answering each other's questions, showing off apps to their friends and facilitators or making recommendations to others for app ideas.

The most ideal collaboration occurred among Aidra, Eric, Donella, Alan and Spike. Aidra and Eric comprised the strongest team as they joined the programme at the same time and kept pace with each other. They worked on separate computers but supported each other by asking and answering questions. Eric was a bit more reserved when it came to talking to the facilitators, but Aidra was very outgoing and would keep facilitators abreast of what the group was doing. When facilitators helped Aidra troubleshoot an issue or gave feedback or recommendations, she would often pass what she learned on to Eric and the others.

Aidra, Eric and Donella collaborated well with their science fair project on ocean pollution, but they were ultimately unable to finish because they had to leave the programme for other commitments including study sessions for standardised testing. Spike and Alan similarly teamed up during the programme, but their time was more focused on socialising than collaborating on the cookbooks. Indeed, each student was more productive at working through the cookbooks on the days when the other partner was not there. They did, however, work well as a pair when they got started on their group science fair project on a topic related to endangered animal species. They started building a website and gathered some research for their presentation during their final day in the programme. Time constraints and obligations outside of the programme (mainly sports) did not allow them to finish the project for the competition.

Unsurprisingly, teams and collaborations tended to be formed based on social relationships. Though these partnerships could be productive, they could also be distracting. For instance, Javier and Simon sat together frequently during the fall semester, and they often socialised or created distractions for each other. Part of the reason for this may have been that Javier stayed further ahead than his partner and would become bored. In this case, giving Javier more reinforcement to leverage his knowledge, skills and role as a peer facilitator may have made the pairing more fruitful.

Ultimately, in the post-test surveys, 40% of students in the fall (8 out of 20; 5 of which came from our selected 9 students) and 25% of students in the spring (2 out of 8) indicated that having friends attend the programme was a reason for their joining. Eric indicated that he told some of his friends (Alan, Spike and likely Donella) to join. This data suggests that students can be motivated to join based on word of mouth. Although it does not conclusively suggest that working with peers was an essential reason for attending for every participant, those who attended the most days tended to have friends who were also regulars in the programme.

Authorship, purpose, and agency

A third integral aspect of the programme design included participants generating their own ideas for apps and creating (or customising) apps reflecting the participants' personal preferences and experiences without following prewritten instructions. Part of the introductory activities for the programme included encouraging participants to generate ideas for apps they would like to create during the programme. Their ideas were often ambitious and seemed to reflect not only their tastes but also their realities. For example, Aidra proposed creating 'an app that helps you get into contact with [an] ambulance or get help faster through your phone'. Javier shared ideas for action-adventure games as well as a digital music store where customers could buy and sell music, which he declined to pursue further out of concern for being sued for selling artists' music without permission. It is interesting to note that Javier was intrigued by the possibility of selling apps to the point that he called the Google Play store from home and talked to a representative about the steps needed to upload and sell his apps. Kettie mentioned that she enjoyed spending time with her mother and also drawing, so she suggested creating a drawing app that they could use together.

As students began to learn how to create apps, they transitioned from working towards their more ambitious ideas to expressing themselves in more modest ways. This self-expression took the form of modifications of the pre-designed apps. These ‘remixes’ ranged from being very moderate, like adding additional media, to fairly advanced, like adding additional code to give the app new features. Alan, for example, edited his first app to include images that he found online rather than use those provided by facilitators. Aidra and Eric added a star field background to one of their games to make it look like a spaceship was flying in space. Aidra edited the text and labels on her screen for contrast with the colourful background and then fine-tuned some of her code in the app to speed up various elements and increase the difficulty. Though these modifications were modest, and in some cases only represented a cosmetic tweak, they represented for many of the students an initial attempt at technology-supported self-expression and, arguably, a nascent form of computational thinking (Brennan & Resnick, 2012).

When students did DIY app activities that required them to start from a blank palette, they tended to gravitate towards the inclusion of cultural (i.e. home, school or pop culture) elements of their choosing. For example, Aidra and Eric each made separate DIY apps that included the use of anime characters. Aidra’s character was trapped in a glass container and would say ‘help me’ when the phone was tapped while Eric’s character was designed to use a popular catchphrase. Aidra also began a second DIY app, which, at various moments in its development, incorporated a musician, a well-known TV and media motivational personality and a comedic online streaming content producer.

Implications and Future Research

In this particular case, the authors gleaned that being part of a social group, having a supportive relationship with the facilitators and feeling the freedom to make choices were all aspects of the learning environment that participants found to be positive. While this observation is not generalisable beyond the context within which this case was drawn, it agrees with the outcomes of prior studies done in similar contexts and with statements made by experts in the emerging body of work on culturally relevant computing (CRC) and work on broadening participation in computing. See Table 2.

[TABLE 2 HERE]

For this reason, the authors suggest further research and development be done that consider scaffolding, group work and student agency as purposeful design aspects of culturally relevant computer science learning environments and as potentially effective approaches to broadening participation. Again, because these factors align with some tenets of culturally relevant computing found in the literature, we suggest future studies continue this investigation within the context of broadening the number and diversity of youth who are exposed to quality educational experiences related to computing and computer science more broadly.

The biggest limitation of the study is that participation was impacted by academics (Aida, Eric, Millisent and Javier), dance (Donella and Kettie) and sports (Alan, Spike and Simon), so making concrete conclusions about the effect of the students' confidence in their ability to use twenty-first century skills on their persistence is difficult. Some of the areas where students saw declines in their scores arguably could be resolved with prolonged exposure to the intervention. For instance, Millisent's diminished scores for communication and the use of technology for teamwork might have been resolved with a stable partner and utilisation of our website's forum for small group collaboration, while Aida and Donella's confidence in designing systematically might have been enhanced by completing the group challenge, which appealed to their mutual interest in competition and Aida's interest (and established engagement) in DIY projects. Future studies may be able to draw stronger connections between intervention strategies and student outcomes and confidence if designers can prevent other activities (e.g., athletics and tutoring) from superseding the intervention. Presenting such data for a longitudinal study would be especially interesting for showing the long- term effects of the instructional design on confidence and persistence.

Disclosure statement

Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Table 1

Participant profiles(n=9)

Student ID*	Gender	Age	Grade level	Race	Days attended	Apps completed	Coins collected
Aidra	F	13	8	AA	15	5	14
Alan	M	14	8	AA	5	3	0
Donella	F	13	8	AA	5	5	1
Eric	M	13	8	AA	14	7	9
Javier	M	12	6	AA	17	8	10
Kettie	F	11	6	AA	8	3	18
Milissent	F	11	6	AA	5	3	8
Simon	M	12	6	AA	11	4	10
Spike	M	14	8	AA	6	3	1

Note: Randomly generated pseudonyms have been used in order to protect the identities of participants

Table 2

Study themes and related CRC frameworks

Theme	***CRC Framework***
Group work	Scott, Sheridan, & Clark, 2015; Rankin & Thomas, 2017
Student agency, self-expression, cultural relevance	Lachney, 2018; Goode, 2008; Scott, Sheridan, & Clark, 2015; Goode & Margolis, 2011; Rankin & Thomas, 2017
Adaptive scaffolding; role models	Goode, 2008; Scott, Sheridan, & Clark, 2015

Appendix A

ICT/21Q results, Fall pre- and posttest

Student	Solve problems		Think critically		Com-municate		Use tech-nology to work in teams		Under-stand and use tech-nology systems		Under-stand and use tech-nology applica-tions	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Aidra	4	4	4	4	4	4	5	5	2	4	2	3
Alan	1	5	2	4	1	5	4	4	1	5	5	4
Donella	5	4	5	4	5	4	3	4	5	5	5	5
Eric[a]	1	4	1	4	1	4	1	5	1	4	1	4
Javier	-	4	-	5	-	5	-	5	-	5	-	-
Kettie	5	5	5	-	3	4	4	4	5	5	5	5
Millisent	4	5	5	1	5	3	5	3	5	5	4	1
Simon[b]	4	5	4	5	5	5	5	5	5	5	5	5
Spike	-	4	-	4	-	4	-	4	-	4	-	4

Student	Write code		Be informa-tionally literate		Be media literate		Use digital tools to research		Design systemat-ically		Be creative	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Aidra	2	3	4	3	4	4	5	3	4	2	5	5
Alan	1	5	1	4	1	5	2	4	1	5	2	4
Donella	4	4	5	4	5	5	5	5	3	1	4	4
Eric[a]	1	1	1	4	1	4	1	4	1	1	1	5
Javier	-	2	-	4	-	4	-	4	-	5	-	5
Kettie	2	5	5	5	1	5	5	5	5	5	5	5
Millisent	1	1	3	5	1	5	-	5	4	1	5	5
Simon[b]	5	5	5	5	4	5	5	5	5	5	5	5
Spike	-	5	-	5	-	5	-	5	-	5	-	3

Note. Lighter shade indicates lower posttest scores than pretest. Darker shade indicates higher posttest scores. No shade indicates that scores remained the same, or that the student was missing either a pre- or posttest score.

[a]Eric answered "1" for each of the questions in the pretest and [b]Simon answered "5" for each of the questions in the posttest, which could be a result of not attending to the questions. Therefore, interpretations related to his attitudes prior to the intervention and gains in these areas should be made cautiously.