Computer Science Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ncse20

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To cite this article: Maya Israel , Moon Y. Chung , Quentin M. Wherfel & Saddeddine Shehab (2020) A descriptive analysis of academic engagement and collaboration of students with autism during elementary computer science, Computer Science Education, 30:4, 444-468, DOI: 10.1080/08993408.2020.1779521

To link to this article: https://doi.org/10.1080/08993408.2020.1779521

Published online: 23 Oct 2020.

COMPUTER SCIENCE EDUCATION
2020, VOL. 30, NO. 4, 444–468
https://doi.org/10.1080/08993408.2020.1779521

A descriptive analysis of academic engagement and collaboration of students with autism during elementary computer science

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ABSTRACT

Background and Context: Elementary computer science (CS) can be engaging and challenging for some students with disabilities who struggle with complex problem solving.
Objective: This study examined academic engagement of students with autism spectrum disorder (ASD) in elementary CS instruction.
Method: A mixed methods case study was used to study how three elementary students with ASD participated in CS instruction that involved a peer collaboration strategy.
Findings: All students were engaged with the computational tasks, with variations in academic engagement. All experienced challenges with the computing activities that resulted in disengagement or limited independent problem solving. Students received "in the moment" supports, with little evidence of planned instructional scaffolding.
Implications: Students did not receive individualized support. With such supports, they may have had a more positive experience. It is important to continue to study the experiences of students with disabilities during elementary CS instruction to better support these learners.

ARTICLE HISTORY
Received 20 December 2019
Accepted 4 June 2020

KEYWORDS
Elementary computer science; students with autism spectrum disorder; academic engagement; collaboration; collaborative-computing observation instrument (C-COI)

Introduction

In the United States, approximately 6.5 million students (13%) in public schools receive special education services due to a disability (U.S. Department of Education, 2015). Importantly, 95% of these learners attend regular schools and spend most of their time in general education classrooms alongside their non-disabled peers (U.S. Department of Education, 2015). Thus, students with disabilities are participating in K-12 computer science (CS) instruction. Even though there is growing attention to the participation of students with disabilities in CS instruction (e.g., the CS for All, 2018), there is little research on the participation of students with cognitive or social-behavioral disabilities in K-12 CS initiatives. In one of only a few such studies, Ratcliff and Anderson (2011) found that students with disabilities benefitted from

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CS education activities within the LOGO programming environment, especially if the students were given supports such as modeling, explicit instruction, opportunities for unplugged activities, and physical activities to support more abstract programming tasks. In another study, Snodgrass et al. (2016) studied the participation of two students with disabilities during computing instruction and found that students' engagement increased when teachers implemented individualized supports (e.g., prompting procedures or behavioral interventions). The authors stated that there is a need for more research to better understand how to tailor strategies to increase both access and engagement in computing CS activities for students with disabilities.

Collaborative problem solving and CS

Within K-12 CS, there is often an emphasis on student collaboration. The K-12 Computer Science Framework (2016) described collaboration as a core computational practice that involves cultivating working relationships, using and establishing team norms, soliciting feedback, and using technological tools that support collaborative computing (K-12 Computer Science Framework, 2016). This emphasis on collaboration typically does not account for implications or supports for students with diverse backgrounds, abilities, or needs.

Previous research suggests that teachers often create situations wherein students collaborate during CS activities (e.g., Ray et al., 2018). Denner et al. (2014) found positive effects when middle school students engaged in pair programming, a type of collaborative computing process wherein two people simultaneously work on one computer to complete a programming task. Teachers often encourage student collaboration during elementary CS instruction through either teacher-facilitated collaboration such as formalized peer tutoring to help students who needed additional support or naturally occurring collaborations in which students independently sought partners with whom to collaborate to complete CS activities together (Israel et al., 2015; Ray et al., 2018). In another study of elementary students' CS-related collaborative interactions, Israel et al. (2017) found that students engaged in three types of collaborative interactions during CS activities: Collaborative problem solving, expressions of excitement or curiosity, and socialization. The authors recommended that future studies embed instructional strategies into these computing activities to facilitate more productive computational conversations.

Although not a major focus in K-12 CS education, scripted conversations are sometimes used to facilitate learning and social interactions within the computer-supported collaborative learning (CSCL) field (e.g., Kollar et al., 2006; Webb et al., 2009). In a meta-analysis of conversation scripting within CSCL activities, Vogel et al. (2016) found that scripted conversations provided students with guidance in how to interact with each other as well as increased learning. Given the potential scripted conversations on collaborative interactions within the CSCL literature, conversation scripting may be impactful within K-12 CS instruction, especially for those students with disabilities who struggle with collaboration within more open collaborative experiences.

Students with autism and collaborative computing

When considering collaboration within K-12 CS education, there may be significant implications for students with Autism Spectrum Disorder (ASD). ASD is considered a neurobiological disorder that impairs social interactions, communication, and behavior (Diagnostic and Statistical Manual; 5th ed.; DSM-V). ASD results in a highly variable set of functional and cognitive profiles, which means that no person with ASD will have the same issues with communication, social interactions, or executive functioning (Center for Disease Control and Prevention, 2012). When considering social interactions, even students with ASD who have the ability to use age-appropriate language often have challenges with social interactions and communication. Consequently, many students with ASD have difficulty collaborating with their peers (Koegel et al., 2012). McGee et al. (1997), for example, compared social behaviors between typically developing children and children with ASD and found that students with ASD had fewer social initiations with peers. It is likely, therefore, that students with ASD may struggle during collaborative problem solving within the context of CS education.

Purpose of the study

The purpose of this study was to examine how elementary students with ASD behaved during CS instruction. Given that students with ASD may struggle with collaboration, this exploratory study began with the assumption that interventions that support collaboration should proactively be built into instruction. Therefore, this study provided an initial investigation of students with ASD within collaborative computing who were taught a collaborative script called the Collaborative Discussion Framework (CDF; Park & Lash, 2014) to facilitate collaboration alongside their peers. The primary research question for this study is as follows: After being introduced to the CDF as a collaboration strategy, what types of academic engagement with the computational tasks, peers, and teachers did the students exhibit? The initial hypotheses were that the introduction of the CDF into the computing instruction would promote increased collaborative problem solving and academic engagement as defined in the methods section.

Materials and methods

This study made use of an instrumental case study approach (Stake, 1994) of three students with ASD at a mid-sized elementary school that included CS in its general education curriculum. These three case studies were considered distinct in that each student had unique strengths and challenges related to communication, socialization, and computing. As Stake (1994) explained, instrumental case studies provide insight into an issue or to refine a theory. Since the purpose of this study was to understand how students with ASD functioned and collaborated within CS instruction, this approach was implemented. Additionally, information from each individual case study was also examined collectively to gain a broader understanding of how the students with ASD functioned within elementary computing classes. Stake (1994) explained that collective case studies are used to “inquire into the phenomenon, population, or general condition” and these cases were chosen to “lead to better understanding, perhaps better theorizing, about a still larger collection of cases" (p. 237). Thus, examining the three cases both independently and collectively allowed for exploration of the unique information from each of these as well as commonalities across the cases.

CS instruction

The curriculum used in this study was Code.org Code Studio (http://code.org), a block-based, visually-intuitive programming environment wherein students drag and connect blocks of commands to complete increasingly complex computing puzzles until they can freely create programs within the Code Studio Play Lab. Code Studio also includes a series of unplugged activities, lessons that teach computing concepts without the use of technology (Prottsman, 2014). Content taught in Code.org Code Studio includes sequencing, looping, nested looping, conditionals, functions, and debugging. For example, sequencing is introduced early in each of the three Code Studio levels. The teachers allowed the students to progress through the Code.org Code Studio puzzles at their own pace and walked around to provide support as students requested support. Each student was provided with their own Chromebook and were encouraged to collaborate with peers sitting next to them. Given that this study was intended to investigate how students participated during "typical" CS instruction, the researchers did not interrupt this instructional delivery with the exception of teaching the students to use a peer collaboration strategy described below.

Instructional strategy: the collaborative discussion framework (CDF) conversation script

To facilitate collaborative problem-solving during CS instruction, students in this study (and their peers) were taught to use a scripted conversation strategy called the Collaborative Discussion Framework (CDF; Park & Lash, 2014). The CDF focused on adaptive help seeking and collaborative interactions by encouraging students to have more robust conversations. This strategy was developed prior to the start of this study because many students exhibited low persistence when confronted with a difficult task and would ask peers or teachers to solve their computing problems when they were stuck. The scripted conversation starters of the CDF involved questions and answers to guide collaborative problem solving. The CDF script includes four guiding questions: (1) What are you trying to do? (2) What have you tried already? (3) What else do you think you can try? (4) What would happen if … ?

The students were explicitly taught to use the CDF through (a) teacher modeling of what to do when stuck on a computing task, (b) student practice with teacher feedback and encouragement, and (c) visual prompts of the CDF by placing posters of the CDF in the classrooms and referring to these when prompting the students to use the CDF (see Figure 1). The three students in this study were encouraged to use the CDF whenever they needed help or when they helped their peers. In this study, no differentiation was made regarding whether or not peers had disabilities, as disability status would not preclude a student from interacting with the study participants in meaningful ways. In this way, the whole-class intervention could support the needs of the students with disabilities without these students feeling singled out for using this strategy.

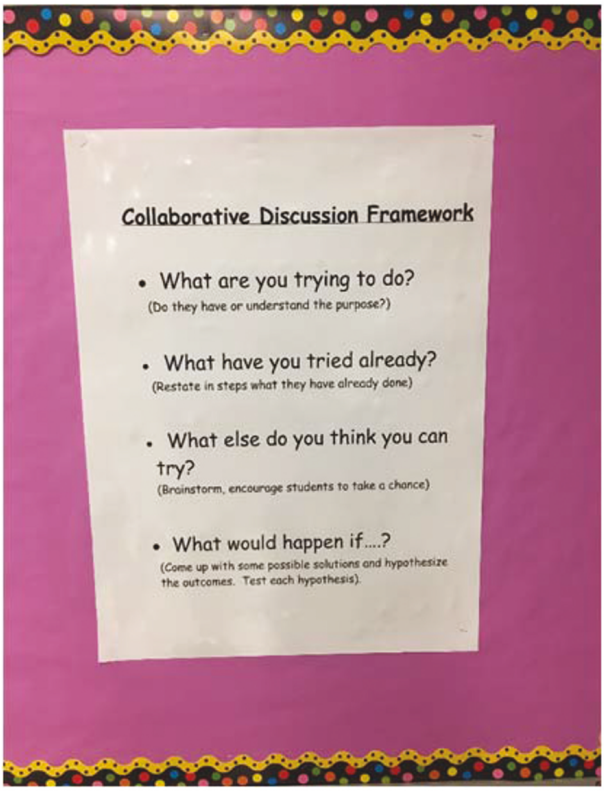

Figure 1. *Classroom poster of the CDF script (*Park & Lash, 2014*) *used with permission.*

Participants

Participants were recruited from a Midwestern elementary school in the United States with a CS for All initiative wherein all students had weekly CS instruction (approximately 45 minutes per week). At the time of this study, 353 students were enrolled in grades K-5. Within this student population, 19% of the students received special education services for documented disabilities and 74% of the students were classified as living in low-income households. The racial/ethnic composition of the school was 41% African-American and 41% Caucasian with the remaining 18% split between Latinx, Asian, and Multiracial.

After approval from the Institutional Review Board, three upper elementary students and their teachers were purposefully selected for this study. The following criteria were used to select student participants: (1) parents provided consent for participation, (2) students received special education services for ASD, and (3) students had basic computer proficiency such as turning on the computer, logging into the CS websites with limited assistance, and use of a mouse or trackpad. Additionally, these three students were selected as they had differing challenges during CS instruction so that they could present enough diversity across context (Stake, 2006). All three students in this study were given pseudonyms and described throughout this study using those pseudonyms. No comparison students were included as the nature of this case study was to evaluate the experiences of students with ASD during computing activities.

Teachers

The one general education teacher and one instructional coach also participated in this study in a limited manner. The classroom teacher was in her second year of teaching CS. She was the primary CS teacher for Bradley and Alex. The instructional coach supported CS instruction in Demetrius's class. These teachers provided contextual information about the students including their observation of how the three students generally participated in CS class as well as their academic performance in core academic content areas. The primary purpose of including these two teachers was to corroborate and triangulate observational and CCOI findings.

Bradley

Bradley was a Caucasian male in third grade. He spent most of the school day in general education. He received special education services for a primary disability of ASD and a secondary disability of attention deficit hyperactivity disorder (ADHD). He did not require the support of a paraeducator. According to Bradley's teacher, he could decode words and do arithmetic calculations, but he had difficulty with complex problem solving, text comprehension, and application and generalization of skills from one context to another. His teacher explained, "I think comprehension is really tough, but he can read anything that you put in front of him … In math, he's really good at his basic math facts, but I think application of those is hard for him" (classroom teacher, interview transcript lines 25–29). She further stated that Bradley was motivated by learning new concepts, completing tasks, and persisting through difficulties that he faced. She explained, "He definitely perseveres a lot through the things he's stuck on, but he also gets frustrated. Once he gets it, he's super excited" (classroom teacher, interview transcript lines 22–23).

Alex

Alex was a Caucasian male in third grade. He was Bradley's twin brother. He spent most of the day in general education and received special education services for the primary disability of ASD. He did not receive support from a paraeducator. Like his brother, Alex had basic computer skills, strong decoding and arithmetic skills, and difficulty with reading comprehension and mathematical application. His teacher explained that Alex is "definitely more introverted [than his brother] but he's also excited when he learns something new" (classroom teacher, interview transcript lines 33–34). Because both brothers were in the same classroom, Alex often followed Bradley around the classroom. The classroom teacher stated that Alex was motivated to learn new things and felt proud of himself when he accomplished a task. However, he also got frustrated quickly when he was stuck on unfamiliar tasks and verbally expressed his frustrations. When frustrated, he typically stopped working rather than asking for help. Alex's teacher stated that he enjoyed being on the computer, especially to play video games. Although Bradley and Alex were twins, both were included in this study because their classroom behaviors differed enough to provide variability and both met the other inclusionary criteria.

Demetrius

Demetrius was an African-American male in fifth grade. He received special education services for a primary disability of ASD and secondary disability of intellectual disability. Demetrius spent most of his school day in general education with one-to-one support from a paraeducator. Demetrius rarely engaged in social interactions with his peers. The technology coach who assisted with computing in Demetrius's class described him as having limited verbal communication although he saw Demetrius's social interactions as improving over the past 2 years. According to his classroom teacher, Demetrius was below the instructional level of his peers in all content areas, generally performing at the first-grade level in reading and mathematics. Both his classroom teacher and technology coach indicated that Demetrius enjoyed using the computer, especially to play arithmetic games. The technology coach further explained, "He is perfectly capable of doing basic level computer IT [information technology]. He can log in, enter his password, use the trackpad … He can do all those things" (Technology coach, interview transcript lines 15–17).

Data collection and analysis

Two primary forms of data were used to gain an understanding of students' behaviors during computing instruction. Classroom observations were used to understand the participants' level of academic engagement and participation during the classroom computing activities. Video screen capture data were then used to examine the students' computing behaviors. Additionally, teacher interviews were conducted after classroom observations were analyzed to gain contextual information about the students and to triangulate findings.

Classroom observation data collection and analysis

Four researchers with experience in both elementary and special education observed the participants during CS instruction. A structured observation protocol was used that replicated procedures outlined in Snodgrass et al. (2016) wherein an interval-based observation process called momentary time sampling was used (Lewis et al., 2014). The observers recorded the level of academic engagement every minute of the students' classroom participation. The observers also noted if and how the students asked for help and whether they used the CDF with peers and adults. The researchers calibrated data collection procedures for consistency prior to beginning classroom observations. Two observers were present for each observation session in order to compare observation notes and conduct interrater reliability checks. This procedure also ensured that video screen capture software was recording the students' computer screens.

Participants were observed multiple times to gain an understanding of how they interacted with peers and teachers as well as with the computing tasks. Bradley and Demetrius were each observed during four computing sessions and Alex was observed during five computing sessions. Teachers confirmed that these observations served as typical instructional situations and that the students' behaviors during these observations were consistent with typical computing behaviors that the teachers observed.

Evaluating students' academic CS engagement

Researchers have defined academic engagement as a complex, multidimensional relationship between persistence, self-regulation, and working towards goals (Christenson et al., 2012). It involves interactions between the student's classroom setting, behaviors within those classroom settings, and connections with adults and peers (Appleton et al., 2008). Because academic engagement is complex, it was evaluated in two ways: (a) level of engagement (from unengaged to engaged using the CDF strategy that was taught in class), and (b) with whom or what the student was engaged (i.e., with the task on the computer, with peers, and/or with the adults). When students were unengaged, the observers described the unengaged behaviors. Definitions of academic engagement used in this study included the follows: (a) unengaged behaviors included not looking at the computer, looking at the computer but working on a non-computing task, and/or talking with others on topics not related to CS, (b) engaged behaviors included looking at the computer screen when the computer screen included CS activities and actively using the trackpad or mouse to do the CS activity, and/or talking with peers or adults about CS activities, and (c) CDF engagement included all aspects of engaged behaviors as well as interactions when the students initiated interactions and/or used the CDF conversation script with peers or teachers to solve the problem. It is important to note that CDF engagement included times when students used the CDF for problem-solving regardless of whether the problem was fully solved and that students could be engaged with the computer and peer/adult at the same time. The total engagement time was then tallied in the categories of (a) engagement with peers, (b) engagement with adults, and (c) engagement with the computer/CS activity. In cases where the student was engaged in a discussion with a peer and adult concurrently, that type of interaction would be recorded as "other" and then described in the field notes. Lastly, the total time of each engagement type was divided by the total time to compute the proportion of each engagement level during observations. Thus, the level of academic engagement was evaluated both quantitatively (i.e., amount of time engaged during CS activities) as well as qualitatively (i.e., field notes describing what the student was doing during the observation).

Video screen recording data collection and analysis

This study replicated a methodology used by Israel et al. (2017) by analyzing video screen recordings of students as they engaged in computing activities. This data was collected using Screencastify (http://www.screencastify.com), a video screen capture program for Google Chrome that captured on-screen actions that occurred during computing instruction and conversations between peers and adults. Data from these video screen captures were analyzed using the Collaborative Computing Observation Instrument (C-COI), which allows researchers to analyze on-screen individual and collaborative behaviors of students during computing activities (see Israel et al., 2016).

The C-COI includes fixed a-priori codes used to analyze video screen recordings of the three students. These codes included nine broad codes with associated *sub-codes* that provided additional details about the students' independent and collaborative behaviors while they engaged in CS activities. Within the C-COI, the codes describe (a) what the student does during the computing activity (i.e., works independently, collaboratively, or on non-computing activity), (b) whether or not the student encounters a problem, (c) if the student was involved in collaborative problem solving or socialization with peers or adults, and (d) how peers or adults respond to the student (Israel et al., 2017, 2016). Figure 2 provides a screen capture of the C-COI interface. Additionally, the researchers took extensive field notes including transcriptions of conversations and creative suggestions given for

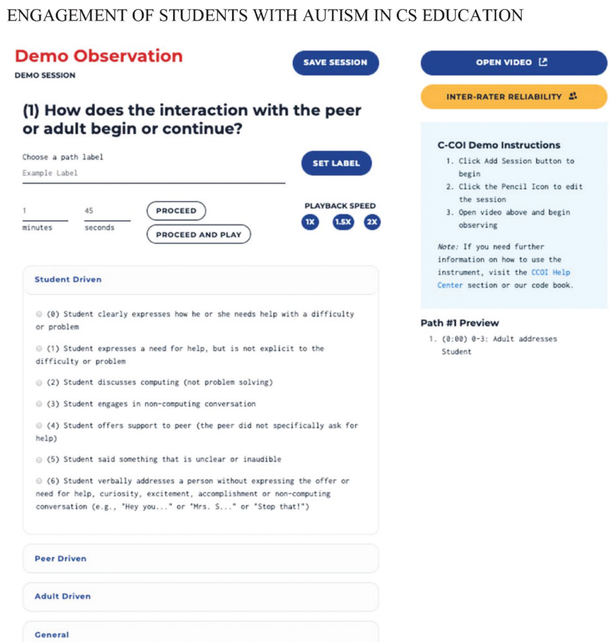

Figure 2. Screenshot of the C-COI interface.

solving problems to accompany the codes. The C-COI analysis was then triangulated with the classroom observation data.

C-COI interrater agreement procedures

Researchers who analyzed C-COI videos underwent extensive training in using the C-COI, which involved viewing and coding videos together to operationalize definitions followed by independently coding videos and checking for consistency. Once the researchers calibrated coding procedures, 20% of the videos in this study were randomly selected to be coded by multiple raters to establish interrater agreement. The reliability procedures used in this study followed recommendations by the C-COI developers and consequently consisted of two levels (see Israel et al., 2016): (a) 100% agreement on the general start and end of events (e.g., interaction or independent problem-solving), and (b) 80% agreement at the sub-code level.

Teacher interviews

Teacher interviews took place after student-level data collection and analysis ended in order to avoid unnecessary research bias that might result from teachers' statements. Teachers were presented with the themes that emerged from the student data in both written form and orally by the researchers. Based on this data, a semi-structured interview protocol was developed to gain specific information about students' individual and collaborative behaviors during both CS instruction and other academic areas such as mathematics. All interviews were audio recorded and transcribed for analysis. Given that these interviews sought specific information about student behaviors and characteristics, no major themes emerged from these interviews. Rather, these interviews provided information that could either corroborate or counter observational data.

Results

The following section provides information about all three students' academic engagement as defined by their participation in the computational tasks, their interactions with peers and adults, and their use of the CDF strategy. In the analysis below, collaboration was described as any interactions that the students had with peers and adults rather than defining collaboration as specific types of interactions given that collaboration may present differently for many students with ASD who struggle with collaboration and communication.

Bradley

Bradley was observed during four computing sessions (103 minutes) in which he worked through computing puzzles in Code.org Code Studio. When CS instruction began, Bradley retrieved his computer, logged into his student account, typed the URL for Code.org Code Studio and entered his credentials into the site without supports. His teacher stated that he enjoyed accomplishments, such as figuring out the correct set of blocks in Code Studio that allowed him to transition to a higher puzzle or level. If Bradley was stuck, he verbally expressed frustration and either went to his teacher or peers for help.

Bradley appeared to be engaged in the computing task for 67% of the time across all four observation sessions. He exhibited a high percentage of engagement with the computing task as well as with peers on three of the four observations. As can be seen in Figure 3, the exception to this high level of engagement was on the third observation, where he appeared distracted. On that day, he appeared to be sick, as he sniffed, used tissues, and then threw the tissues away several times.

Observation notes indicated that he was unengaged from the computing activity and focusing on another task in the room until his teacher redirected him back to the computing task. Towards the end of class, however, he became interested in the computing work of a friend and began discussing his friend's work for a short time. Overall,

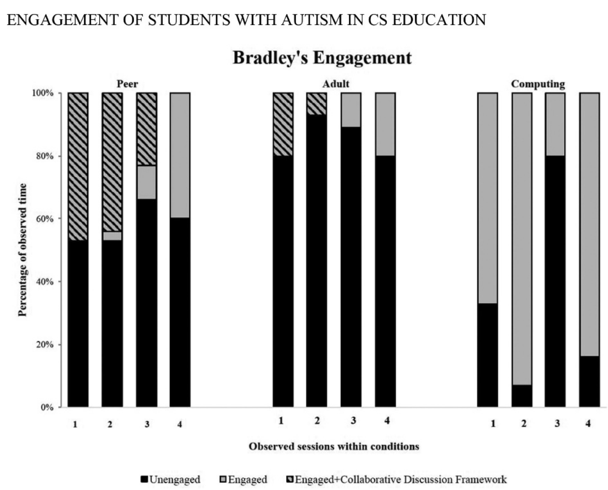

Figure 3. Bradley's engagement during CS activities.

Bradley was engaged with his peers 42% of the observation time. On the last observation, Bradley worked independently for most of the session. At one point, he became excited about his work. He expressed to his teacher that he won two trophies within Code.org Code Studio and asked her to see his work. He and his teacher discussed the blocks he used. On two other occasions, he indirectly sought help by looking at his peers and stating, "Nooooo. This is confusing!" and "This is extremely hard. I can't do it." He did not use the CDF conversation script, but rather asked his peers how to solve the computing puzzles. Figure 3 represents Bradley's engagement across sessions as related to engagement with peers, adults, and the computer.

When engaged in on the CS tasks, he worked individually or with a peer on attempting to complete the Code Studio puzzles. It was common for Bradley to immediately ask for help from a peer after starting a new puzzle. For example, on Observation 1, he asked his friend, "Ronnie, can I have some help? Ronnie, you are not helping me!" On Observation 2, when Bradley asked for help, his peer, Samantha, asked him to demonstrate the actions he wanted to perform on the computer with his body. At that point, Bradley moved to the carpet and attempted to perform the task physically by walking in a square, as that was the step that he could not figure out in Code Studio (see Figure 4 for a screen capture of Bradley's project). He sat down at his computer once again and attempted to program the actions he physically performed on the carpet. After a couple of minutes, he stated, "No one is helping me. This is just not fair." At that point, Bradley's teacher asked whether he attempted to solve the computing task with the CDF to which he replied that he did. She brought her chair to his desk and gave him verbal prompting to help him problem solve the task.

Bradley's use of the CDF was mostly superficial. He often asked for help from his peers, and his peers responded with the CDF questions to prompt this problem solving. However, Bradley would answer their CDF questions without specificity. For example, on Observation 3, when a peer asked "What have you tried already?" Bradley answered by saying, "I don't even know." Although Bradley could use the CDF, he did so more as a strict script than as a method to prompt authentic conversations. In another example from the third observation session, Bradley took his computer to join Samantha who was helping

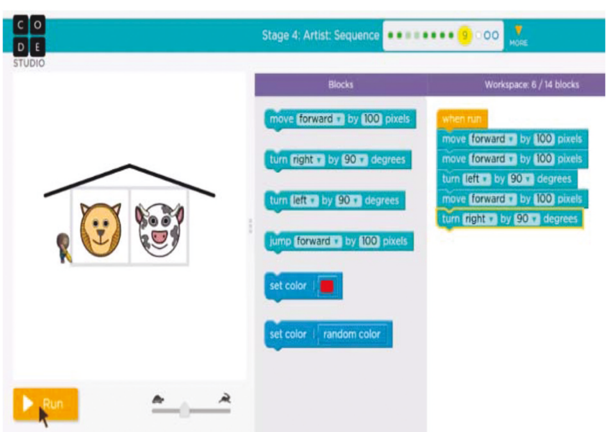

Figure 4. Example of Bradley's computing task.

a friend. He used the questions in the CDF but appeared to do so more as a cue card rather than to begin authentic interactions. That is, he asked Samantha each of the four questions in the CDF in order without follow up questions and without using her answers to prompt additional conversation. When unengaged, Bradley either chatted with friends about off-task topics or expressed frustration.

Additionally, Bradley rarely interacted with adults (approximately 14.5% of the time). Bradley did not ask the teacher for help unless she approached him first to check his work. In fact, Ms. Post, this teacher, explained that when Bradley experienced an unfamiliar task, he often "just shuts down" (Classroom teacher, interview transcript line 167). She stated that she believed Bradley was showing slow improvement in this area. Many of the interactions between Bradley and Ms. Post involved her coaching him to problem solve in a step-by-step manner.

Below was a partial transcript in which Ms. Post approached Bradley and attempted to help him with his CS activity.

Ms. Post: "What did you do?"

Bradley: "I went *move forward, move forward, left, move forward."*

Ms. Post: What else do you have to do?

Bradley: I think I got to go right [pauses for two seconds] two times. [Bradley then dragged the *turn right by 90 degrees* block.] I think it would work.

Ms. Post: What's gonna happen when he turns right?

Bradley: No. He has to turn right two times.

Ms. Post: Which way is right?

Bradley: Right there.

Ms. Post: Look at this. If you go this way, what way is that? This is my *what* hand?

Bradley: [Pause for three seconds] The left.

Ms. Post: Ooohhhhh!

Bradley: No, see. That is right.

Ms. Post: So which way does he have to turn?

Bradley: Left.

They continued to work together. Although the problem was not solved completely, Bradley expressed excitement because he succeeded in moving his sprite.

C-COI analysis confirmed the classroom observation data. In one collaborative event that lasted for 11 minutes, for example, wherein Bradley worked through a Code.org Code Studio puzzle, Bradley had six different communications that fell into three types of interactions: (1) Bradley addressed a peer twice seeking help with a computing task, (2) he once was approached by his teacher and communicated with her about a problem he faced, and (3) on three occasions, he was approached by a peer without initiating that interaction because the peer noticed that Bradley was struggling. These interactions are related to problem-solving within the context of CS. Unlike his peers, who had more varied types of interactions that included a combination of problem solving, computing-related conversations, and socialization, Bradley's conversations all focused on solving computational problems. Bradley's peers had to ask probing questions to ascertain how to help him as he did not explicitly state his difficulty. A partial transcript of a conversation between Bradley and his peers is provided below:

Peer: What are you trying to do? That?

Bradley: Yes, I am trying to go up, so do you put a circle, do you … [student is interrupted by his peer].

Peer: What have you tried already?

Bradley: Yeah, that worked, this worked.

Peer: Let me see. They pressed *Run.*

Peer: See, that does not work because [pauses for three seconds], what else do you think you can try?

Bradley: I can't do this. Oh gosh!

Peer: What would happen if you put a right or left?

Bradley: Let us see if left works okay? [Bradley drags the *turn left by 90 degrees* block into the coding interface.]

Peer: On the top. [Bradley places the *turn left by 90 degrees* block above the two *moves forwards* blocks. Then, he pressed *reset* and ran the code. A message appears: "You are using all of the necessary types of blocks, but try using more of these types of blocks to complete this puzzle."]

Bradley: Seeeeee! You have to have two *move forwards*.

Peer: You put the *left* at the bottom. [Bradley places the *left by 90 degrees* block at the bottom of the two *moves forwards* blocks. He pressed *reset* and runs the code. A message appears: "You are using all of the necessary types of blocks, but try using more of these types of blocks to complete this puzzle".

Bradley: There is not left!

Peer: No. You see, you turn left and then move forward.

Bradley: And then what left and then? [The peer stopped talking to Bradley and the problem was not solved.]

This conversation illustrated the frustration Bradley experienced as he tried to program the house in the puzzle (see Figure 4). He could draw the bottom line of the house and turn the sprite to the left, but he could not figure out how to move the sprite up to build the side of the house. In this and other interactions between Bradley and his peers, the peer typically facilitated the use of the CDF and attempted to coach Bradley, who struggled with how the blocks could be used together to complete the task as well as with sequencing and directionality.

Alex

Alex was observed during five computing sessions in which he worked in the Code.org Code Studio. Alex could retrieve his assigned computer, access the Code.org website, and enter his username and password. Across all five observations, Alex was actively engaged with the computer and CS tasks 80% of the time. Figure 5 represents his engagement patterns across the sessions as related to his peers, adults, and the computing tasks. He engaged in conversations about computing with his peers 31% of the time and with his teacher 16% of the time.

Within the times that Alex was actively engaged in communicating with his peers, he displayed CDF engagement 37% of the time. During these times, Alex did independently ask for help when he got stuck and communicated with a peer about coding through the CDF questions. Within those CDF engagement instances, Alex tended to solve or get close to figuring out a computing difficulty he faced. Additionally, when he solved the problem or moved on to the next level, he verbally expressed his excitement such as “Yes! I did it, I did it! I’m on level seven” (Observation notes, Observation 1) or boast to himself, “Wow, this is easy. Wow, really easy!” (Observation notes, Observation 3).

When Alex was unengaged with the computing task, it was often in response to frustration with being unable to solve the problem. For example, on one occasion, Alex struggled to figure out the correct code, and within 2 min of working, he got frustrated and made the “awwwww” sound. He then stopped working and simply sat at his computer (Observation notes, Observation 4).

Often, Alex asked for help before attempting to work independently on the computing task. In these instances, because Alex did not attempt to solve the computing task prior to asking for help, the conversation was unproductive. For example, on Observation 2, after Alex asked a peer for help, the peer responded by using the CDF and asked, “What did you try?” Alex did not respond, so the teacher prompted Alex by asking, “What did you need to do?” Alex responded to his peer and the teacher by saying, “I didn’t try anything.” At this point, his peer left the conversation, but the teacher remained with Alex to offer additional prompting to solve the

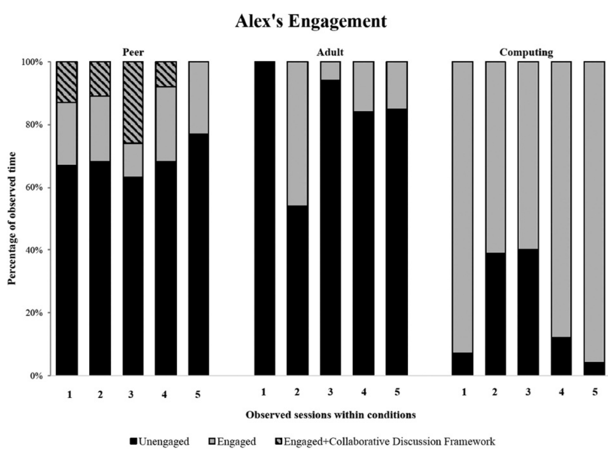

Figure 5. Alex’s engagement during CS activities.

computing puzzle. After the teacher left, Alex immediately sought help from another peer on a new computing puzzle. The peer stated that he was familiar with the coding task. The first peer that Alex interacted with on the previous problem then joined the new peer to help Alex. The two peers took control of the computer and mouse to try to solve the computing puzzle. When they did not immediately solve the puzzle, Alex said, "What?. …. No!" The peers attempted again successfully. Alex then independently tried to solve the next puzzle for a few seconds unsuccessfully and said, "I hate code. I hate it." At that point, he pushed his chair away from the computer and said, "I didn't even get to play. I'm mad." At other times, Alex's peers were more successful in helping him by offering step-by-step directions. For example, on Observation 3, when Alex asked for help, his peer told him the specific directions and blocks to use. Alex then followed these explicit directions alongside his peer.

A 10-min event captured through C-COI analysis exemplified how Alex interacted with his peers. In this event, Alex interacted with peers three times by requesting help when he encountered a challenge. In the first two instances, Alex did not explicitly explain his difficulty; rather, he told his peers that he needed help and waited for the peers to gain the necessary information by looking at his computer. During both of these instances, even with the peer's assistance, Alex's problem remained unsolved. The peer tried to offer explanations or ask questions and then left Alex to solve the problem on his own. After less than 2 min of independently attempting to solve the problem with the information provided by the peer, Alex asked for help from a third peer. The new peer came to his desk and used the CDF to attempt to ascertain Alex's difficulty. Again, Alex did not explicitly explain his problem to the peer. This time, however, Alex looked at his peer's computer to see if his peer was on the same coding puzzle, which provided some necessary information. After the peer left, Alex attempted again to solve the computing puzzle independently and was successful. The following example was the first interactive instance with the second peer.

Alex: Did you pass this level?

Peer: Ehhh, yes.

Alex: I do not know what it is, but I did this correct. See? [Alex presses the *Run* button to show the peer what he did so far].

Peer: Yes, you did, but I know how to do it. You need *right*, I think [Alex follow's his peer's directions] and push *forward*. [Alex did not follow the peer's direction this time; instead, he clicked *Run*]. I did this before. Trust me man. Check if it works.

[Alex clicks *run*. A message appeared: "You are using all of the necessary types of blocks, but try using more of these types of blocks to complete this puzzle]

Alex: Ohhhh

Peer: Aye!

Alex: Ahhh [Alex's voice indicated frustration]. This is so hard! Can you show your computer? [Alex moves the *turn right by 45 degrees* and *move forward by 100 pixels* blocks into the trash]

Peer: I am not at that level. I am on a different level, man. I cannot remember how to do this.

Alex: Yeah, me either.

Like Bradley, Alex spent most of the computing time on task and engaged. However, he had difficulty understanding the purpose of each programming block and how these blocks worked to create a program. Despite these challenges, he was motivated to learn and got close to solving the computing problems through the interaction with his peers.

Demetrius

Demetrius was observed during four computing sessions in which he worked on Code.org's Code Studio puzzles. He could take his computer to his desk independently. To log into Code Studio, Demetrius used a cue card with step-by-step directions to enter his student account and type the URL for Code.org. With the use of this cue card, he could successfully log into Code Studio.

He often engaged in self-talk during computing time. For example, on Observation 1, he repeated the phrase, "Let's get started!" during the class. Demetrius was engaged with the computing puzzles 82% of the time, although this level of engagement often involved returning to play with the computational puzzles he previously completed rather than working on new ones. For example, during Observation 2, he exhibited high engagement with the Code Studio puzzles; however, when looking at the video screen capture of that day, Demetrius was observed rerunning computing puzzles that he previously completed and watching the "Flurb" (i.e., the creature) get to the treasure in each level. He did not do any new programming on this day.

During all observations, Demetrius did not attempt to complete new computing tasks unless prompted by an adult and sometimes preferred other computer-based activities. For example, on Observation 3, Demetrius was playing a *Curious George* video game on the computer when his teacher informed the class that they were going to start coding. He switched to Code Studio and began to ask for help from one of the research assistants in the classroom as his instructional aide was not yet in the classroom. The research assistant offered cues and verbal prompts until the puzzle was solved. At that point, Demetrius turned off Screencastify and switched back to the *Curious George* video game. The research assistant decided not to restart the video screen recording as Demetrius was becoming agitated. He then played this game until it was time to move onto another class activity.

Figure 6 showcases Demetrius's engagement patterns across the sessions as related to peers, his teachers, and the computing tasks. Demetrius did not interact with his peers during any of the observations, and all interactions observed were initiated by the paraeducator. According to the technology coach, his lack of collaboration was primarily due to his lack of functional communication.

Demetrius's computing behavior was best characterized as a cycle of working independently for a few seconds on a computing puzzle he previously completed or working unsuccessfully on a new puzzle for a couple of seconds followed by skipping to another puzzle and repeating the cycle. The amount of time he persisted independently on any given puzzle was low (Median = 21 s, Range = 12–89 s).

In some instances, the paraeducator took over Demetrius's computer and mouse because she was unsuccessful in helping him through verbal prompting and support.

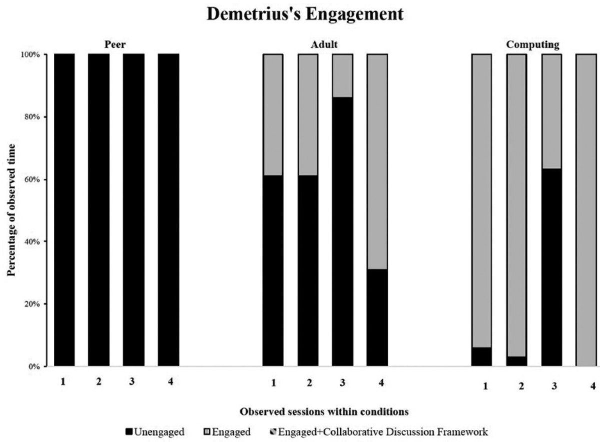

Figure 6. Demetrius's engagement during CS activities.

For example, on Observation 2, Demetrius remained on the same computing puzzle for over 20 min with little success. During this time, the paraeducator sat near Demetrius. He worked on the computing puzzle for a few seconds and then became distracted. The paraeducator attempted to redirect him to the task. Video screen capture data indicated that rather than using a *repeat* block, which was necessary to complete the task, Demetrius continued to add additional *move forward* blocks for his code. The paraeducator used verbal prompts to attempt to help Demetrius understands the code. After approximately 20 min, the paraeducator took over the computer and mouse for 2 min. She then handed the computer back to him and pointed towards blocks that were needed to solve the computing puzzle successfully.

Demetrius did not independently attempt to interact with his peers, teacher or paraeducator. If interactions did occur, these interactions almost always occurred because the paraeducator or teacher initiated those interactions. For example, on Observation 4, within the 16-min observation, Demetrius did not interact with his peers even though his peers were near him physically. This was consistent with other observations. He interacted with the paraeducator for 11 minutes. These interactions were all initiated by the paraeducator and involved the paraeducator assisting him in problem-solving when he was stuck. On the one occasion that Demetrius initiated communication with the paraeducator and asked for help, the paraeducator explained to him that she did not know how to help. She was not familiar enough with the computational task he was attempting to complete.

When examining Demetrius's interactions with the C-COI, most common interactive behaviors were initiated by the paraeducator while he was working independently. The paraeducator usually began the interactions by asking Demetrius questions about his computing/programming activities. She asked him questions to attempt to help him focus on the task. These types of interactions typically ended in Demetrius ignoring the paraeducator, as per the transcript below:

Paraeducator: Do you know what that means? Every time you see a question mark you have to add a number? Can you click in that? Click on that number?

Demetrius: [ignores and changes levels]

Although Demetrius participated in the computing activity, the quality of his participation was low. He exhibited the repetitious behavior of starting a computing puzzle and immediately pressing *run* without manipulating any blocks. After approximately 20–30 seconds, he would skip to the next puzzle and repeat the same behavior.

Discussion

In this study, three students with ASD participated in CS activities alongside their peers. All three students were engaged in these activities for much of the instructional time with varied levels of engagement and participation. Each student, however, struggled with both the content of those CS activities and with working collaboratively with their peers. Two important findings emerged from this study that will be discussed in detail below. First, the students all had difficulty persisting and working through computing problems, and they did not receive sufficient support in addressing these challenges. Although there was a great deal of student frustration and the students received "in the moment" help, there was little teacher planned individualization or scaffolding. Second, although the scripted questions of the CDF were taught to promote elaborated discussions and to guide students' interactions, the CDF on its own did not provide enough support to these learners. There was evidence of the peers using the CDF with the students, but the discussions that emerged did not necessarily lead to increased student success with their computational tasks. The central take-away findings from this study, therefore, were that although the participants received "in the moment" support during the CS activities, there was limited proactive planning to address their needs beyond the use of the CDF, and the CDF, on its own, was insufficient in meeting their instructional needs.

Student challenges with the computational tasks

Most CS educational activities require multiple steps, and those steps may not be clearly defined. Although the students in this study could complete the process of getting their computers and signing into the computing platform, both the observations and C-COI revealed several challenges including a lack of understanding of the programming blocks and/or how the blocks could be used to solve the computing puzzles. Because the students in this study struggled with completing the computational activities, they either gave up quickly or got frustrated and abandoned the tasks. In two of the cases, the students immediately asked or received support from a peer or adult. Serious consideration, therefore, must be given to how instruction can be delivered in a manner that minimizes frustration for students who struggle with complex multi-step problems.

Whether intentionally or not, the adults and peers in this study did provide explicit instruction to the students during the CS activities, which often consisted of explaining specific actions to take to solve their computational problem. This explicit instruction was implemented in reaction to the students' difficulties and frustration rather than proactively to mediate the difficulties. For example, in analyzing the conversation between Ms. Post and Bradley, it became clear that Bradley was struggling with visual spatial planning of his project. Ms. Post provided verbal prompting to assist Bradley with understanding which direction the sprite should move. This finding was consistent with results from previous studies (e.g., Knight et al., 2019; Ratcliff & Anderson, 2011) in which students with disabilities engaged in computing activities when provided additional supports that included explicit instruction.

Explicit instruction, however, involves a range of strategies beyond those observed in this study such as verbal prompting, modeling, and immediate feedback. These strategies aim to move students toward mastery by breaking down information into meaningful chunks, so the students are not overwhelmed and immediately give up (Archer & Hughes, 2011). When considering how to use explicit instruction within elementary CS contexts, questions emerge about how to provide the right amount of instruction to address students' needs while maintaining the integrity of the more open-ended approaches that predicate many computing experiences. Returning to Ms. Post's interaction with Bradley, more effective instruction may have included explicit instruction to support visual spatial planning of his project through both physical movement and robotics wherein Bradley could see the robot turn and move in specific directions. Once Bradley demonstrated mastery of this skill with the physical robot, Ms. Post could transition to the computer-based activity more effectively. Future research should therefore examine how to (a) proactively build in some explicit instruction into computing tasks and (b) balance explicit instruction within computing instruction in a manner that allows for student creativity and choice alongside effective modeling and feedback.

The current study also resulted in implications related to the need to examine the students' individualized supports. Snodgrass et al. (2016), for example, found that prior to implementing each student's individualized supports, the students exhibited limited engagement in computing. Once the individualized supports that were used across the school day were introduced into these students' computing activities (e.g., verbal prompting, use of students' positive behavior support chart to reinforce on-task behaviors), their engagement increased. Thus, they showcased the need to tailor instructional supports to the individuals with disabilities in order to increase access and engagement within CS. These findings were unsurprising as there is a great deal of evidence that students with disabilities can be successful in academic learning, including the STEM areas, once they are provided with individualized supports (e.g., Knight et al., 2019; Snodgrass et al., 2016). In the current study, the initial hypothesis was that the use of the CDF discussion script would help the students collaboratively problem solve, but this strategy on its own was not sufficient. It was not individualized and tailored to the unique needs of the students. Additionally, the explicit instruction that was used occurred in reaction to difficulty rather than proactively to attempt to remediate some of the challenges faced by the students.

Locus of control and CS academic engagement

For Bradley and Alex, the observation and C-COI analysis revealed that academic engagement was related to level of perceived success with the computing tasks. When they made progress, the students were engaged in the computational task. When they were stuck, they often became frustrated and stopped working. For these two students, the connection between perceived success or failure and academic engagement mirrors studies related to learned helplessness, attribution theory and locus of control. Ability, effort, task difficulty, and luck have been described as attributions for either perceived success or failure (Weiner, 1985). Within these attributions, locus of control refers to the location of the cause of success or failure (e.g., internal or external to the individual) and controllability refers to the student being able to affect the cause of success or failure such as the amount of preparation (Weiner, 1985, 2010). When students have control of the outcome (e.g., they have strategies such as proactively planning their steps to attempt to solve the problem), then they are more likely to persist in increasingly difficult tasks. On the other hand, after repeated unsuccessful attempts of solving a task, students can develop performance-avoidance tendencies and eventually learned helplessness manifests (Jarvis & Seifert, 2002). These behaviors include giving up easily and asking for help the instant a difficulty is experienced, which was observed in both Bradley's and Alex's data.

It was difficult to tell whether learned helplessness or attribution theory explained Demetrius' computing behaviors, as he enjoyed running programs that he previously completed and was engaged with these activities. He did not attempt new computing puzzles unless the paraeducator encouraged and scaffolded these experiences for him. When he was observed on other computer-based activities, such as playing the *Curious George* video game, he did not exhibit these same behaviors. Because of his limited functional verbal ability, it was difficult to tell whether he chose to spend his time on already-completed puzzles because of frustration with new tasks or because he simply liked to experience the completed puzzles.

Future research should also focus on using non-verbal communication strategies to support students with ASD that have limited verbal communication. For example, many individuals with ASD prefer learning using visual materials rather than by listening (Cohen, 1998). Because of these preferences, there is evidence suggesting that visual supports can lead to positive outcomes to help students such as Demetrius's express needs, challenges, and make requests of teachers and peers. Examples of such supports include Picture Exchange Communication System (PECS; Bondy & Frost, 1994) and social stories (Gray & Garand, 1993). The visual supports could be pictures with words cuing the next step in a problem-solving strategy or a request for help. It can also involve a cue to maintain attention, represent a concept in a concrete manner, or help the student express thoughts (Rao & Gagie, 2006). These supports should be studied within the context of computing in order to effectively make these strategies available to students with ASD within computing activities and to see whether they can be used to increase academic engagement for students such as Demetrius. It is important to remember that Demetrius demonstrated computer literacy both in his ability to play computer games and in his ability to log into and run some of the puzzles in Code Studio. The problem was that he was unengaged in the computational activity within the classroom. His lack of engagement was unrelated to his computer literacy skills.

Peer collaboration and CDF challenges

Given the focus on collaboration within the K-12 CS education community (K-12 Computer Science Framework, 2016), it was critical to examine how the students in this study interacted with their peers. Each of the students in this study had different levels of social and communication strengths and deficits. This finding was consistent with the literature about social and communication challenges of students with ASD (e.g., Koegel et al., 2012; McGee et al., 1997). For example, although Bradley and Alex could verbally communicate with their peers and teachers, the communication script of the CDF only afforded limited support. The CDF provided a method for the students to ask for help. It also gave the peers an initial routine for interacting with the students. However, these interactions did not prove to be particularly helpful in either supporting the students in solving the computing tasks or promoting more authentic interactions. For Demetrius, who had limited verbal communication, the CDF was not effective as he could not verbally ask for help or provide answers to the instructional aide if she asked questions from the CDF. For him, it would be helpful to modify the CDF script so that the instructional aide or peers could say things such as, "You tried to move the sprite left. I wonder what would happen if we moved it right?" Although the students in this study received support from peers, teachers, and the paraeducator, none of the students received enough support to allow them to navigate the computing experiences successfully.

Findings related to the limited impact of the scripted communication of the CDF leads to further questions about how to leverage the advantages of scripted conversations within computing instruction, especially for students with disabilities. For example, it appeared that at least for Bradley and Alex, there should have been a step prior to the CDF that could potentially create the conditions for the CDF to be more effective. Because they immediately requested help, the students in this study might benefit from strategies related to self-regulation to help them moderate frustration. Self-regulation refers to the process that allows students to engage in goal-directed activities (Karoly, 1993; Schunk & Zimmerman, 1994). Self-regulation is likely critical to success in CS due to its importance for successful planning, problem-solving, and choice making. Additionally, several studies tied self-regulation with joint engagement (defined as experiences wherein children engaged in an activity with another person) and academic success (Jahromi et al., 2013). Future research should investigate the relationship between self-regulation, collaborative problem solving, and computing for students with disabilities. Finally, future iterations of the CDF with visual supports and cues could potentially increase the efficacy of this tool. Visual supports in the CDF could potentially focus students' attention to the conversation starters and questions and make the CDF less abstract. There is evidence that visual supports can support learning for students, especially those with ASD (e.g., Weng & Bouck, 2019). Future research should investigate how and to what extent visual supports can enhance the use of the CDF.

Limitations

This study should be viewed in the context of several limitations. First, although the participants in this study were recruited with specific criteria related to disability diagnosis and basic computing ability, the limited number of participants limits the generalizability of findings. Replication studies will be necessary to ascertain whether the challenges faced by the three students in this study are consistent with other students with ASD. Second, this study only included four or five observations for each of the participant's computing and collaborative behaviors. Although this number of observations was consistent with recommendations for C-COI and most CSCL studies examine what make single collaborative experiences successful or unsuccessful (Barron et al., 2009), additional observations focused on the relationship between time, communication, and learning could lead to a fuller understanding of the temporal dimensions of discourse and learning (Mercer, 2008). Third, the current study only included data collection within computing instruction. Lastly, although the study made use of the C-COI, a validated instrument with strong reliability measures, given the complexity of measuring academic engagement, there might be aspects of academic engagement in computing that were not captured through this instrument alongside the observations. For example, this study did not include student or parent interviews or other measures of self-regulation or persistence. Future research should include additional measures to triangulate observational and C-COI data.

Conclusions

This study provided an initial lens into the academic engagement of students with ASD during computing instruction. Findings support the assertion that some students require individualized support beyond the CDF to actively engage in the CS activities. These findings are important to consider to better understand how all learners, including those with disabilities, can attain Papert's (1980) hope that computing can be a broad learning tool. The present study provides important directions for future research on the integration of the CDF alongside strategies for metacognitive self-regulation and additional explicit instruction.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Research reported in this publication was supported by the National Science Foundation STEM+C program [Award # 1639837]. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Science Foundation.

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