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Instructional supports for students with disabilities in K-5 computing: Findings from a cross-case analysis

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ABSTRACT

As computer programming and computational thinking (CT) become more integrated into K-12 instruction, content teachers and special educators need to understand how to provide instructional supports to a wide range of learners, including students with disabilities. This cross-case analysis study examined the supports that two students with disabilities, who were initially disengaged during computing activities, received during computing instruction. Data revealed that students' support needs during computing activities were not CT-specific. Rather, supports specific to these students' needs that were successful in other educational areas were also successful and sufficient in CT. Although additional studies would need to be conducted to ascertain the transferability of these findings to other contexts and students, our results contribute evidence that students with disabilities can and should participate in CT and be provided with the supports they need, just as in all other areas of the curriculum. We present a framework for evaluating student engagement to identify student-specific supports and, when needed, refine the emerging K-12 CT pedagogy to facilitate full participation of all students. We then offer a list of four implications for practice based on the findings.

1. Introduction

1.1. *Integrating computing into the general education curriculum*

There is growing consensus that computational thinking should be included in K-12 education as one of the science, technology, engineering and mathematics (STEM) areas. One of the main arguments for this integration is that computational thinking can help students learn how to think through unstructured problems, interpret data, and communicate using computers (Lee, Martin, & Apone, 2014). Another argument for teaching computing in K-12 is one of equity, given the historic and persistent underrepresentation of women, people from diverse cultural backgrounds, and people with disabilities in computing fields (NSF, 2015). Kafai and Burke (2015) explained that increasing participation in computing can only occur when a broad range of students have access to effective computing instruction that engages them in personally meaningful ways.

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Many terms have been used to describe this academic discipline including *computing*, *computational thinking*, *coding*, and *computer programming*. Although there is no widespread consensus regarding terminology, computational thinking (CT) is generally used to describe the range of computing experiences that include problem solving, designing systems, and finding solutions by thinking in computational ways (Wing, 2006). Aho (2012) further elucidated this definition by stating that CT is "the thought process involved in formulating problems so that their solutions can be represented as computational steps and algorithms" (p. 832).

Given the increased efforts to provide K-12 students with CT experiences, there has been a proliferation of computing software, curricula, and instructional modules targeting young learners. Many of these tools have been designed with a "low floor, high ceiling" (Grover & Pea, 2013, p. 40) so that children can access these software with limited understanding, and as their understanding and proficiency increases, the software are powerful enough to allow for advanced programming. Two common tools used in K-12 CT instruction include *Code.org* and *Scratch*. *Code.org* (https://code.org/) includes leveled modules in which students work through progressively more complex computer programming puzzles that make use of graphically intuitive programming "blocks" in a game-like environment that scaffolds learning about computing and computational thinking, with leveled modules beginning in the primary grades. *Scratch* (https://scratch.mit.edu/) is a programming language that also makes use of graphically intuitive "blocks" wherein students can create stories, animations, and games. It is intended to be an open inquiry computing platform where students can design and share projects. Although not the only computing tools, these two platforms are popular and ones that were used as part of the current study.

Despite the availability of these and other instructional computing tools, there is still little research regarding how to teach CT in K-12, especially with students from diverse backgrounds (Grover & Pea, 2013; Guzdial, 2015). The pedagogical approaches that are available typically come from instruction within higher education. For example, Morrison, Margulieux, and Guzdial (2015) studied the use of worked examples and subgoal labels with students at a technical university and found that these pedagogical approaches were helpful. Such approaches have not been sufficiently studied within the limited K-12 CT literature. Additionally, there is even less focus on investigating how incorporating cognitive accessibility features that have shown to be effective in other content areas (such as Universal Design for Learning [UDL] principles or incorporating explicit instruction alongside open inquiry) can be applied to CT instruction to meet the needs of all students, including students who struggle and students with disabilities (Israel, Pearson, Tapia, Wherfel, & Reese, 2015; Israel, Wherfel, Pearson, Shehab, & Tapia, 2015).

According to the most recent statistics available, approximately 13% of students in K-12 schools have disabilities, 95% of students with disabilities attend regular schools, and a majority of those students spend 80% or more of their school day in general education (U.S. Department of Education, 2015). Consequently, although the Individuals with Disabilities Education Act (IDEA, 2004) affirms that students with disabilities have a right to access the general education curriculum in the least restrictive environment identified by their educational teams, educators have little direction as to how to provide computing instruction and supports that meets the individual needs of students with disabilities in a manner that upholds the intent of the law. The majority of students with disabilities, however, are capable of engaging in computing and computational thinking with appropriate supports and accessible technologies (Ladner & Israel, in press; Stefik & Ladner, 2015).

Education policy within the IDEA as well as the Elementary and Secondary Education Act (otherwise known as the No Child Left Behind Act, 2001) has been moving towards a clear preference towards educating students with disabilities alongside their peers to increase equity and access, which should be extended to computing education opportunities. These policies are consistent with other policies including the United Nations Convention on the Rights of Persons with Disabilities (CRPD) that elucidates that persons with disabilities have a right to non-discrimination, equality of opportunity, and full and effective participation and inclusion in society (Article 3). Ladner (2014) proposed using the CRPD as a blueprint for considering issues related to access of persons with disabilities in computing. The good news is that when students with disabilities receive the proper supports and gain the necessary technical and self-determination skills, their opportunities within the computing fields increase (Burgstahler, Ladner, & Bellman, 2012). Centers, such as Access Computing (http://www.washington.edu/accesscomputing/) and AccessCS10K (http://www.washington.edu/accesscomputing/accesscs10k), have developed programs focused on increasing participation of people with disabilities in computing fields and have illustrated that, with the right supports, students with disabilities can experience a great deal of success learning computing. As computing becomes increasingly integrated into K-12 instruction, there is an opportunity to investigate the experiences and instructional supports that students with disabilities have during CT instruction. Therefore, the purposes of this study were to examine the participation of students with disabilities and their support needs during computing instruction.

1.2. Conceptualizing disability through supports

Disability is often perceived as an inherent, unchangeable characteristic of an individual (World Health Organization, 2013). Through this deficit model, the person with the disability is seen as lacking inherent skills and attributes that are necessary for success. However, while disability certainly involves the presence of health conditions and their effects on the person, the current views of disability acknowledge the social complexities surrounding disability and the influence of contextual factors, which include environmental factors (e.g., social attitudes, accessibility of physical spaces) and personal factors (e.g., gender, race) (WHO, 2002; 2013). Thus, disability can be broadly defined as the "negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors)" (WHO, 2013, p. 8). By defining it in this way, disability can become a fluid experience, diminishing when supports are put into place that eliminate the "mismatch between personal competency and environmental demands" and amplified when those supports are not available (Thompson et al., 2009, p. 136). Take, for example, a person with poor vision. With eyeglasses in place, the person experiences no mismatch between their personal competency (i.e., ability to see) and reading the street signs and noticing landmarks to navigate their neighborhood. Without glasses, that mismatch suddenly becomes quite acute. The eyeglasses serve as the support that bridges the mismatch between personal competency and environmental demands and a "life with meaningful activities and positive personal outcomes" (Thompson et al., 2009, p. 136). In the absence of the needed supports, the individual experiences disability.

Supports are defined as "resources and strategies that enhance human functioning," and individuals with disabilities, therefore, have support needs that typically endure across time and setting (Thompson et al., 2009). The role of a child's educational team is to identify support needs that students require above and beyond instructional practices and put those supports in place to minimize the mismatch between the demands of school and the child's personal competence.

1.3. Connecting individualized supports and Universally Designed computing pedagogy

The above definition of supports highlights the difference between resources and strategies (i.e., supports) that facilitate full participation of students with disabilities and universally designed instructional pedagogies, which are the general teaching practices educators use to teach all learners. Universally designed instructional pedagogies rest on the UDL principles (see http://www.cast.org/), which provide a guide for designing flexible instruction that proactively plans for the diversity of students in today's classrooms and posits that teachers should consider instructional goals, methods, assessments and materials (including technologies) to address learner differences (Meo, 2008; Rose & Meyer, 2002). Thus, UDL is an instructional planning framework for class wide instruction that meets the needs of a broad range of learners.

Although inextricably linked, the distinction between supports and universally-design pedagogy is important. While efforts to define universally designed instructional pedagogy in K-12 CT are ongoing, few researchers have examined how to embed the individualized supports of K-12 students with disabilities into universally designed computing instruction (Israel, Pearson et al., 2015). Thus, this study focused on students' individual needs and associated supports rather than on class wide, universally-designed instructional pedagogies.

1.4. Research aim

As CT is increasingly integrated into K-12 schools, questions arise about how students with disabilities and other struggling learners will access this new content. The purpose of this study, therefore, was to examine the participation and support needs of students with disabilities during computing instruction. We asked the following research question: To what extent are CT-specific supports needed for students with disabilities to meaningfully engage in CT instruction and activities? Our initial hypothesis was that some students with disabilities would require CT-specific supports to successfully and meaningfully engage with instructional CT activities. To explore this question, we conducted two case studies and a cross-case analysis (Merriam, 2001; Stake, 2006; Yin, 2009) of two students with disabilities as they participated in CT instruction and activities.

2. Methods

We conducted these two individual case studies of two children who were receiving special education services at Kranston Elementary School[1] in a midsized urban community in the Midwestern United States. Kranston Elementary School had instituted an integrated computing initiative in which each classroom (a) engaged in 45 min per week of CT instruction, and (b) integrated CT content into mathematics instruction. CT instruction was a structured "computing time" one day each week in which students had time to individually and collaboratively either work through the *Code.org* modules intended for K-5 learners (http://code.org) or engaged in CT activities within *Scratch* (https://scratch.mit.edu/). These were sometimes supplemented by short (5–10 min) mini-lessons led by the teacher or one of the students to demonstrate functions within *Code.org* or *Scratch*. To integrate CT and mathematics, the general education teachers taught one unit at the end of the Spring 2015 school year in which they taught their district-mandated mathematics curriculum, but added supplementary computing activities within *Scratch*. After introducing this integrated content, students were often allowed to spend part of their "computing time" in *Code.org* and part of their time in *Scratch*. The cases presented here are part of ongoing research examining equitable and accessible CT instruction.

This cross-case research was approved by the Institutional Review Board of the university and the two students had parental permission to participate in research and provided verbal and behavioral assent to researchers' observations. Their general education teachers had consented to researchers observing their classroom, and all teachers and the paraprofessional who contributed to this study provided informed consent to participate in the research. Throughout, we use footnotes to indicate from which data source(s) statements are supported.

[1] All names of people and places are pseudonyms.

2.1. Participants

We were interested in examining the experiences of students with disabilities within computing instruction and purposefully selected two cases that represented "diversity across context" (Stake, 2006, p. 23). To give us the opportunity to learn about the varying contexts and complexities that exist within the group of students with disabilities in CT instruction at Kranston, we selected two students, Horatio and Deacon, who had different disabilities, different general and special education teachers, and different levels of adult support and support needs in school. Horatio's disability impacted his functioning in school across all domains and he received pervasive supports throughout his school day for both social and academic performance while the impact of Deacon's disability required only intermittent supports for behavior and specific academic subjects at the time of this study. We also selected these two students because their teachers reported that these students were struggling to engage with and master the content presented during CT instruction and related activities. For each student, we sought participation of the adults responsible for providing supports (i.e., general and special education teachers, support staff).

2.1.1. Horatio

Horatio was an African American male in fourth grade in Mr. Night's general education class. Horatio received special education services under the categories of autism and intellectual disability.[2] Autism (i.e., autism spectrum disorder) is characterized by difficulty engaging in social communication and social interactions, which may include very limited spoken language, and by the presence of restricted or repetitive behaviors or interests, such as strict adherence to a schedule and routines or repetitive motor movement (American Psychological Association [APA], 2013). Intellectual disability represents "significant limitation both in intellectual functioning and in adaptive behavior as expressed in conceptual, social, and practical adaptive skills" that originates before the age of 18 (Schalock et al., 2012, p. 1). Horatio spent a majority of his day in the general education classroom with support from Mrs. Sheraton, a paraprofessional (a.k.a., teacher's assistant) from the special education department who was assigned to provide one-on-one support to Horatio throughout the school day. Each day, Horatio left the general education classroom to receive special education services for 160 min with his special education teacher, Mr. Kingsley. Once a week, he left the general education classroom for speech-language therapy for 90 min and for social work services for 60 min.[3] Mr. Night (general education teacher), Mr. Kingsley (special education teacher), and Mrs. Sheraton (paraprofessional) all participated in this study.

Horatio seemed to be a welcome member of his class, although he rarely initiated contact with his peers. For example, Horatio loved to be chased by his peers during recess. He would not ask his friends to play with him, but, because his classmates knew he liked it, they would often chase him without his request. The school social worker had been trying to encourage Horatio to ask his classmates to engage in this activity and to chase them in return, but he had not yet done this without explicit directions from an adult.[4] He rarely initiated interaction or conversation with other people and did not take turns without being told to do so.[5] He often talked softly to himself, using words and phrases that others could not understand or repeating lines from his favorite TV shows, but he was not usually disruptive to the class.[6] He struggled to hold conversations with others, rarely engaging in reciprocal turn-taking or directing his speech to another person. When speaking to others, he mostly used very short phrases or single-word responses and made only intermittent eye contact.[7]

Horatio was compliant and easily followed multi-step directions from others.[8] He willingly and promptly followed directions from his teachers most of the time. He read at an approximately second grade level, but struggled to respond to comprehension questions posed by his teachers.[9] His teachers reported that he seemed to enjoy math more than reading in school.[10] Horatio also enjoyed working and playing on the computer. He liked listening to electronic books from the local public library's website, playing on literacy websites (e.g., *Starfall.com*), and would willingly participate in computing activities on both *Code.org* and *Scratch*. He could operate a computer competently and without modifications.[11] For example, when it was time for computing instruction, Horatio would retrieve his computer, log in to his student account, type *Code.org* into the browser search bar, and enter his credentials to the site independently.[12]

2.1.2. Deacon

Deacon was a Caucasian male in fifth grade in Mrs. Moore's general education class. Deacon was born with fetal alcohol syndrome (FAS) and was receiving special education services under the educational category of Other Health Impairment

[2] Mr. Kingsley Interview Transcript.
[3] Mr. Kingsley and Mrs. Sheraton Interview Transcripts.
[4] Mrs. Sheraton and Mr. Night Interview Transcripts.
[5] Mrs. Sheraton Interview Transcript, Mr. Night Interview Transcript, Observation notes.
[6] Mr. Kingsley and Mrs. Sheraton Interview Transcript, Observation notes.
[7] Mr. Night Interview Transcript, Observation notes.
[8] Mrs. Sheraton Interview Transcript, Mr. Night Interview Transcript, Observation notes.
[9] Mrs. Sheraton and Mr. Night Interview Transcripts.
[10] Mrs. Sheraton Interview Transcript.
[11] Mrs. Sheraton, Mr. Night, and Mr. Kingsley Interview Transcripts, Observation notes.
[12] Observation notes, 2/11.

(OHI) and Learning Disability (LD). OHI is an educational category that is used when a student experiences, "limited strength, vitality, or alertness … that is due to chronic or acute health problems … and adversely affects a child's educational performance" (IDEA, 2004; Sec. 300.8). LD is characterized as "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations" (IDEA, 2004; Sec. 300.8). As a result of FAS, Deacon struggled with maintaining attention to and completing tasks or consistently engaging in socially appropriate behavior. He also had a learning disability that primarily affected his ability to read, understand text, and write.[13]

Deacon spent a majority of his school day in Mrs. Moore's general education classroom. His special education teacher, Mrs. Williams, came into his general education classroom to provide supports during math and for his behavior for a small portion of his school day, and Deacon left the general education classroom to receive 40 min of one-on-one or small group instruction in reading with Mrs. Williams each day. Deacon received additional support while he was in the general education classroom from a paraprofessional for 60 min each day in reading, writing, and behavior.[14] Once a week, he left the general education classroom to attend a 30-min small group session with the social worker to help him develop social skills, including strategies for coping with frustration. Mrs. Moore (general education teacher) and Mrs. Williams (special education teacher) both participated in this study.

Deacon was articulate and had established reciprocal friendships with multiple peers in his class. He enjoyed time on the computer over most other activities during his school day. He loved to play *Minecraft* (an online game wherein players can build things using three-dimensional virtual building blocks) and worked with several of his classmates to build components within the co-constructed *Minecraft* space. Deacon was able to do all grade level academic tasks with minimal supports from his special education team (e.g., additional explanations or demonstrations), but he required pervasive supports to maintain attention to and complete these tasks and to self-regulate his behavior throughout the school day. Both Mrs. Moore and Mrs. Williams reported that Deacon struggled most with staying on task and impulsivity and that he often refused to do work or follow instructions.[15] On most school days, there were multiple instances in which Deacon would refuse to complete a task, lose attention on a task he had started and begin wandering around the classroom, or spend so much of his time distracted by other activities or people that he would not finish the task in the allotted amount of time. To hold him accountable to how he spent his time at school, each day, Deacon had to discuss his daily behavior report with his special education teacher as a part of his Behavior Intervention Plan.[16] This support was coupled with other incentives for completing tasks (e.g., getting to self-select a computer game after completing an assigned task) and with an arrangement made between his teachers and guardians that he had to continue working during afternoon recess or stay after school to complete any assigned tasks that he did not complete during the school day. With these supports, Deacon was successfully participating in his general education class.

2.2. Data collection

We collected data on both children through repeated observation of their weekly computing time in their general education classroom and through in-depth, semi-structured interviews with their teachers over the course of the spring semester of the school year. To ensure prolonged field engagement (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005), we completed the data collection activities over the course of a semester and engaged in data analysis with two researchers who had been observing CT activities in this school for three years. We also created an audit trail that documented this engagement, storing all field notes and interview recordings and transcripts on a secure university server (Brantlinger et al., 2005).

2.2.1. Observations

The first author, a doctoral student in special education with seven years of public school teaching experience in special education, observed Horatio eight times and Deacon six times for approximately 30 min per observation; that is, she observed every weekly computing time within one semester until data saturation was achieved (i.e., observations were conducted until observations resulted in the same findings). To facilitate collection of observation data relevant to the research questions, we used an observation guide adapted from the Scale for Teachers' Assessment of Routine Engagements (STARE; McWilliam & Freund, 2006). STARE encourages the observer to look at what the individual of interest is doing, how he participates, what he can do on his own, and his communication and social skills. We used these categories to organize our field notes of the observations. As the observer watched the students engage in computing activities, she made a note approximately every minute of the student's engagement with adults, peers, and materials (e.g., if the student was talking with an adult or peer about the computing task; if the student was using materials related to the computing task); these notes were used to estimate the amount of time each student spent engaged with the CT activity, reported subsequently and in Figs. 1 and 2. She also collected field notes about Horatio's and Deacon's need for supports during computing activities by recording general

[13] Mrs. Williams Member Check response.
[14] Mrs. Williams Member Check response.
[15] Mrs. Moore/Mrs. Williams Interview Transcript, p. 3.
[16] Mrs. Williams Member Check response.

observations of what other students in the class were doing and what Horatio and Deacon were doing to allow us to compare the activities and identify their support needs.

2.2.2. Interviews

We conducted semi-structured interviews with Horatio's general education teacher, Mr. Night, and his one-on-one paraprofessional, Mrs. Sheraton. Horatio's special education teacher, Mr. Kingsley, communicated with the research team through email and answered questions in written format instead of through a face-to-face interview. We also conducted a semi-structured interview with Deacon's general education teacher, Mrs. Moore, and his special education teacher, Mrs. Williams, together at their request. Because of his communication disorder, Horatio could not participate in a direct interview; to maintain consistency across case studies, we chose not to interview the students.

2.3. Data analysis

Data analysis occurred in two stages, following the recommendations of Stake (2006) and Yin (2009) for conducting a cross-case analysis. We first completed an analysis of each student's case independently (i.e., within-case analysis) to develop an explanation of his or her support needs in CT. Then, we used these reports to complete a cross-case analysis to answer the research question (i.e., To what extent are CT-specific supports needed for students with disabilities to meaningfully engage in CT instruction and activities?).

2.3.1. Within-case analysis

To analyze the data collected for each case, we transcribed the audio-recorded interviews, compiled the observation notes, and calculated an approximate amount of time each student spent engaged in the CT activity using the observation notes. With these sources, we then used explanation building to develop a narrative about the experiences of each student during computing time (Yin, 2009). We used Yin's four-step process for conducting explanation building within a single case: (1) make a theoretical explanatory statement about the phenomenon of interest (here, the student's experience during computing instruction time), (2) compare this statement to the data from a single case, (3) revise the theoretical statement to better reflect the case, and (4) review the revised statement against the data from the case. We then reconstituted the data from each student into a narrative description of the explanation we developed for each case, presented in the following section.

2.3.2. Cross-case analysis

Again, using the procedures set forth by Stake (2006) and Yin (2009), the research team first read both narrative accounts of the individual cases and then discussed possible explanatory statements, comparing their interpretations with one another and the data and discussing the explanatory statements until consensus was reached. We did this to confirm that our final explanatory statements were defensible and in alignment with data collected and the purpose of this study. Then, the

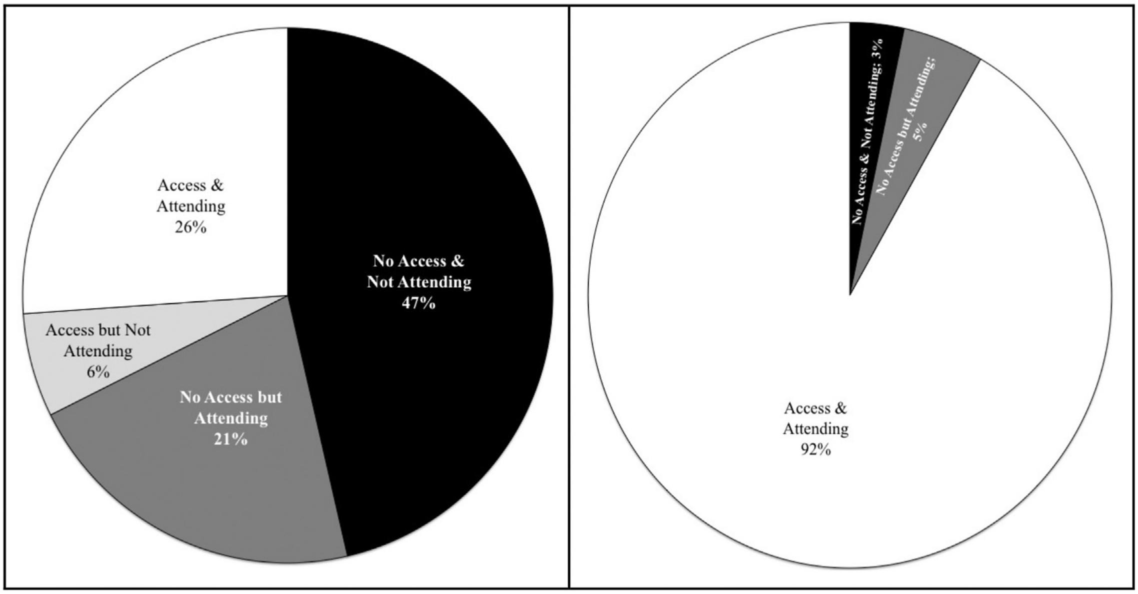

Fig. 1. Pie charts represent the approximate amount of time Horatio had access to the computer and the approximate amount of time he was attending to the computing task. The pie chart on the left represents six observations totaling 206 min during which the paraprofessional was providing support. The chart on the right represents two observations totaling 60 min during which the researcher and paraprofessional were providing alternative supports.

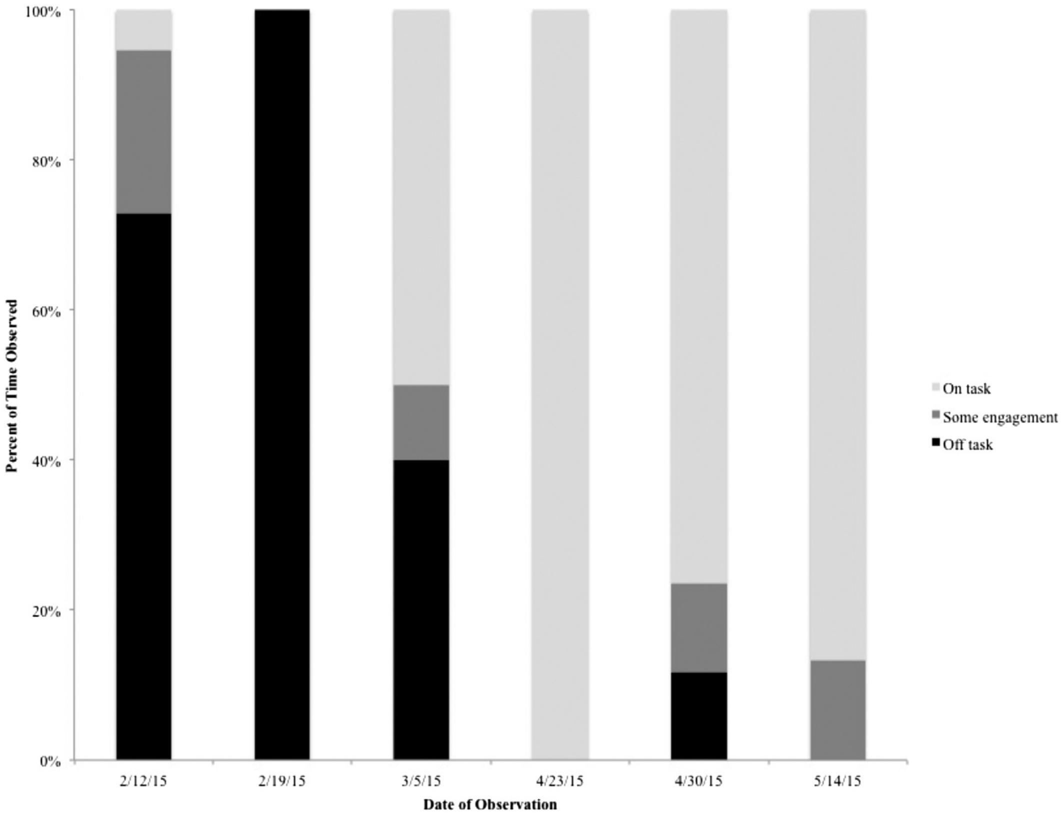

Fig. 2. A graph representing the approximate number of minutes Deacon spent off task (black), somewhat engaged (dark gray), or on task (light gray) during each observation of coding activities. On March 5th, Mrs. Moore initiated supports (i.e., reward for completing task; consequence for being off-task).

researcher team discussed the two cases and used the separate explanatory statements from each to develop a cross-case assertion (Stake, 2006) about the support needs and experiences of students with disabilities in CT instruction at Kranston Elementary School.

2.3.3. Ensuring quality

To increase the level of trustworthiness and credibility of the data analysis, we examined several data sources that offered different perspectives (i.e., teacher and support staff interviews and classroom observations). We also made every effort to purposefully engage with our biases and expectations and seek disconfirming evidence to each theoretical statement we made (Patton, 2015). We incorporate a description of how disconfirming evidence influenced our theoretical explanations in the narrative below. Additionally, we sent each child's story to the adult participants, asking them to corroborate the explanatory statements made about each student, to verify the accuracy of the narrative description we created of the students' experiences, and offer any other comments on the report they wanted us to consider (Brantlinger et al., 2005). All but two adult participants responded to this member check. Minor revisions were made to our participant description of Deacon and no other revisions were suggested.

3. Results

We present each within-case analysis first, followed by the cross-case analysis. As stated previously, our initial theoretical explanatory statement to explain the supports these students with disabilities needed to participate and experience success in CT activities was as follows:

> Students with disabilities require CT-specific supports to successfully engage with instructional CT activities, and when these supports are not available, students with disabilities cannot meaningfully engage in those activities.

We based this explanation on two sources. First, we hypothesized that the absence of people with disabilities in the computing fields might be, in part, due to the absence of the necessary CT-specific supports to enable them to learn the skills necessary for participation. Second, the teachers at Kranston raised concerns about the extent to which students with disabilities were participating in the CT instruction and activities they were incorporating in the school's curriculum. The teachers requested that the research team help them identify the CT supports they needed to put in place to facilitate the participation of students with disabilities. The teachers and researchers had discussed various CT-specific supports to explore, including visual directions for completing *Code.org* modules, using guided access and other accessibility features on the computers, and providing extended direct instruction for students who were struggling. Thus, we anticipated that this explanatory statement would answer our research question.

3.1. Horatio's story

Every Thursday, Horatio's class dedicated 30–45 min to practicing the computing and computational thinking skills they had been learning throughout the week by spending this time engaged in computing activities, usually on *Code.org* or *Scratch* (i.e., "computing time"). On a typical Thursday during computing time, Horatio would eagerly retrieve his computer from the computer cart along with his peers, log in to his student online account, and get on *Code.org* or *Scratch*. Mrs. Sheraton, his one-on-one assistant watched from her desk that was placed next to Horatio's desk in the back corner of Mr. Night's classroom. If Horatio had trouble logging into the computer, Mrs. Sheraton would take his computer and try to figure out what was going wrong.[17] When she got him logged in, she would hand the computer back to him.

Some days, the session began with a mini-lesson about computing led by Mr. Night, his student teacher, or another member of the Kranston staff. During these occasional mini-lessons, Horatio would sometimes look up at the instructor, indicating his attention; other times, he would log on to one of his favorite websites to play literacy games until the mini-lesson ended.[18]

Most days, the class spent the entire session engaged in computing on *Code.org* or *Scratch*. On these days, once Horatio got into the computing program, Mrs. Sheraton would look over his shoulder, watching his attempts to figure out the coding tasks. Typically, as soon as he made an error, Mrs. Sheraton would take the computer and try to work out how to solve the computing task. As she worked, she would describe what she was doing to Horatio and give the computer back to him to run the program by clicking on the final block or tile to run the code she had built. Sometimes, Horatio paid attention, looked at the computer screen as Mrs. Sheraton worked, and responded to her directions (see light gray slice in the pie chart on the left in Fig. 1).[19] Other times, Horatio seemed to be lost in his own thoughts, talking softly to himself and playing with his fingers while he waited for the computer to be returned to him (see black slice in the pie chart on the left in Fig. 1).[20] Across six observation sessions, each lasting between 30 and 38 min, Mrs. Sheraton had Horatio's computer for approximately 68% of the time, trying to figure out what he was supposed to do (see black and dark gray slices in the pie chart on the left in Fig. 1). The rest of the time, Horatio had access to his computer (32% of the time; see white and light gray slices in the pie chart on the left in Fig. 1), and, when he did, he was generally fully attentive to the task at hand (26% of the time; see light gray slice in the pie chart on the left in Fig. 1).

3.1.1. Supports?

As part of his Individualized Education Program (IEP) developed to meet his educational needs and support him in the areas impacted by his disability, Horatio had received one-on-one adult support from a paraprofessional for most, if not all, of his school career, and Mrs. Sheraton had provided that support to him in first, third, and, now, fourth grade.[21] His teachers expressed how essential they felt this support was to Horatio's participation and engagement throughout the school day, but they also identified concerns about how this one-on-one adult support was influencing Horatio's progress. They recounted how, because an adult was exclusively attending to him for most of his school day, the paraprofessional and other teachers would often modify expectations during activities to accommodate the skills they perceived Horatio as having. For example, Mrs. Sheraton recounted an experience when Horatio was in third grade and the class was expected to animate an art project on *Scratch*. Mrs. Sheraton explained,

> I said to the teacher, "How much of this does he need to do?" And she said, "He can go on *Scratch* and do whatever he wants to." So, he drew pictures. We didn't save them. We didn't color them in, but he played. I mean, he was involved with it the whole period doing what he wanted to do.[22]

Thus, it was difficult for his teachers to tell just how much Horatio could do on his own. As Mr. Night, his general education teacher, put it,

> I felt last week like he had actually accomplished something on *Code.org*, but … a lot of the times when I see those little victories and accomplishments, I'm wondering, how much was it him working independently? How much does [Mrs. Sheraton] come into play? … I'm afraid it's more the latter.[23]

[17] Observation notes, 2/25, 4/15.
[18] Observation notes, 2/25, 4/8, 4/22.
[19] Observation notes, 2/4, 2/11, 2/18, 2/25, 4/8, 4/15.
[20] Observation notes, 2/4, 2/11, 2/18, 2/25, 4/8, 4/15.
[21] Mrs. Sheraton Interview Transcript, p. 1.
[22] Mrs. Sheraton Interview Transcript, p. 13.
[23] Mr. Night Interview Transcript, p. 5.

Mrs. Sheraton also explained

> All I did [during computing time] was do [the coding] all the time and had him watch me. I'd have to poke him every once in awhile [to get his attention and] look at me. And I would talk to him about it.[24] … I would talk to him about what I was doing, but I never know what he hears and what he retains.[25]

In addition to their uncertainty about Horatio's skills, his teachers raised concerns about their own abilities to successfully support Horatio. Computing and CT were foreign concepts for Mrs. Sheraton and she often felt overwhelmed with the task of supporting Horatio during this activity. In her own words, she explained:

> I wish I was 30 years younger. … What I can do on a computer is very little. I can get on my email. I can get on *Facebook*. That's all I need. I can look up things on the Internet. That's all I do. If I had to type a letter to somebody, I'd have to ask my husband. He has this thing called *Word*. I'd have to get in there and type it and then he'd have to print it. Cause I've never done that.[26] [Horatio] needs somebody who knows what they're doing, …cause I don't know how to do anything.[27]

Mr. Night also expressed some discomfort with his computing skills but indicated more concern with the level of expectation put on him for an entire class. He said,

> I was getting the feeling that the expectation was on me, the classroom teacher, to … figure out where to go with [computing], and how to solve the problem. And, I think I bristle a little bit at that because I'm not a coding expert. I've got six subjects a day I'm teaching and 24 kids …. I was told that I'm responsible as a classroom teacher, to keep [practicing] my coding, … but to keep at it and to stay where the [students are] and to stay supportive and encourage them. … I take some stabs at it sometimes. But, you know.[28]

In addition to these class-wide responsibilities, Mr. Night expressed regret and concern about the level of attention he was able to give to Horatio, saying:

> A few months go by, you look back and go, "Wow …, he's just not on my radar like he should be." [29] One of my only regrets this year is just that I didn't do more one-on-one with [Horatio]. … Reading group, math, coding time, any technology. Any time. I just wish. If I could do it again, I would probably try to carve out some more one-on-one with him.[30]

Although Mr. Kingsley, Horatio's special education teacher, was not with Horatio during computing time, he too expressed concerns about his own ability to support both Mrs. Sheraton and Horatio in this area, stating:

> I have tried to use hand-over-hand strategies for the computer and peer mentoring to keep him on task. These have not been too successful … … I think it might be helpful to have someone come in and show his teaching assistant and myself what we can do to make him more independent with coding.[31]

Thus, Horatio's teachers had questions and concerns about the supports they were providing and about their ability to provide those supports both in CT and in other areas of school. Mr. Night was concerned about being able to provide sufficient supports to Horatio without neglecting his other students and while still keeping up on all of his other teaching responsibilities[32]; Mrs. Sheraton was concerned about how her own proficiency with technology and CT might interfere with her ability to support Horatio's learning,[33] and she was accustomed to modifying the expectations placed on Horatio for completing activities across content areas[34]; Mr. Kingsley had not found supports that worked for Horatio and needed new ideas to try.

3.1.2. Revisiting our explanation

Our research question came out of teachers' reports that Horatio and other students with disabilities were struggling to engage in CT, and our initial explanatory statement assumed that students were struggling because (a) there were content-specific features of CT that required CT-specific supports, and (b) teachers indicated that they were relatively unfamiliar with CT content and therefore could not identify those CT-specific supports. Our initial explanation was, "*Students with disabilities require CT-specific supports to successfully engage with instructional CT activities, and when these supports are not available,*

[24] Mrs. Sheraton Interview Transcript, p. 8.
[25] Mrs. Sheraton Interview Transcript, p. 9.
[26] Mrs. Sheraton Interview Transcript, p. 19.
[27] Mrs. Sheraton Interview Transcript, p. 12.
[28] Mr. Night Interview Transcript, p. 13.
[29] Mr. Night Interview Transcript, p. 2.
[30] Mr. Night Interview Transcript, p. 4.
[31] Mr. Kingsley Interview Response, p. 1.
[32] Mr. Night Interview Transcript, p. 2, 4.
[33] Mrs. Sheraton Interview Transcript, p. 12.
[34] Mrs. Sheraton Interview Transcript, p. 13.

students with disabilities cannot meaningfully engage in those activities." Mr. Night, Mr. Kingsley, and Mrs. Sheraton had each expressed their insecurities about the supports they were providing during CT, and, in our observation of Horatio's experience during computing time, he had little access to his computer (see pie chart on the left in Fig. 1). As his teachers reported when Horatio was recruited for this study, he experienced very little success during computing time. Thus, the data we had collected to this point supported this original explanatory statement to some extent, namely that, as needed supports were not available, Horatio could not meaningfully engage in CT activities. However, in our interviews with his teachers, we discovered that Horatio experienced minimal direct participation throughout the school day, not only during CT instruction and activities. Thus, we did not feel we had sufficient evidence to support the claim that there were CT-specific supports that Horatio needed. We modified our explanatory statement for Horatio's experience as follows:

> *There are supports specific to Horatio's needs that he requires to successfully engage with instructional activities. His teachers and support staff had difficulty identifying these supports across the subject areas, including CT, so he was not meaningfully engaged in those activities.*

3.1.3. Surprise!

Because we had completed a sufficient number of observations and these observations revealed consistent findings regarding Horatio's lack of engagement, we asked for permission to try something with Horatio. On April 22, when Horatio ran into difficulty with a *Code.org* activity and Mrs. Sheraton took the computer to try to figure it out, the researcher asked if she could help. Mrs. Sheraton agreed gladly.[35] The researcher, who also had minimal competence with CT, placed the computer back in front of Horatio and gave him verbal directions of things he could try to solve the computing task. Horatio complied with all directions and also tried some of his own ideas. When he got stuck, the researcher demonstrated options he could try, leaving the computer in front of him and giving control back whenever he pushed her hand off the computer. Together, Horatio, Mrs. Sheraton, and the researcher successfully completed two tasks on *Code.org* without taking the computer from him.[36]

After this observation, the class missed several weeks of computing time due to statewide testing and school-wide assemblies. The next session was on May 20. On this day, Mrs. Sheraton asked the researcher to help.[37] Horatio logged into *Code.org* independently and began to work on the computing puzzle. With two verbal directions from the researcher and one from Mrs. Sheraton, Horatio successfully completed the computing puzzle. Then, while the researcher and Mrs. Sheraton observed, he successfully completed the following two puzzles without any assistance. Both the researcher and Mrs. Sheraton were shocked by his ability to compute and to problem solve. As Mrs. Sheraton put it, “I was just flabbergasted, because he's never done that! … He never tried and it's like [he said], ‘Give it to me. I'm doing it today.’ … That was fun!”[38]

It turned out that the supports Horatio needed were far simpler than anyone expected. His engagement increased dramatically once he was provided with access to the computer, verbal directions, models of how to complete the computing tasks, and options to try when he ran into trouble with the computing tasks. With these supports in place, Horatio had access and attended to the computing tasks for approximately 83% of the time on April 22 and 100% of the time on May 20 (see pie chart on the right in Fig. 1),[39] spending all of that time on the task assigned to the rest of the class without modifications to the expectations while experiencing success (i.e., completing levels in *Code.org*). In addition, Horatio demonstrated far greater skill than anyone had expected and was fully engaged with the CT tasks during that time.

No one knew how Horatio learned these computing skills. Had Horatio learned how to do all this from watching Mrs. Sheraton and listening to her explanations during previous computing times? Was he actually listening to and learning from the mini-lessons and other instruction he had appeared to be ignoring? Had he learned CT skills somewhere outside of school? During these last two sessions, the researcher and Mrs. Sheraton provided four basic supports: (a) access to materials, (b) verbal directions about what to do and how to do it, (c) models of problem-solving techniques (e.g., watching the researcher try different combinations of programming blocks on *Code.org*), and (d) models of how to complete the assigned task (e.g., watching the researcher complete an activity on *Code.org* with the computer in front of him). Would Horatio experience similar success in other subject areas if these same supports were provided? Our methods did not allow us to answer these questions. However, we must account for this experience in our explanation of Horatio's previous lack of success with CT activities.

3.1.4. Finalizing our explanation

Our working explanation prior to these sessions was:

> “*There are supports specific to Horatio's needs that he requires to successfully engage with instructional activities. His teachers and support staff had difficulty identifying these supports across the subject areas, including CT, so he was not meaningfully engaged in those activities.*”

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[35] Observation notes, 4/22.
[36] Observation notes, 4/22.
[37] Observation notes, 5/20.
[38] Mrs. Sheraton Interview Transcript, p. 9.
[39] Observation notes, 4/22, 5/20.

Given that we cannot know how he learned the skills he displayed on these final two observations, and given that he experienced success with computing tasks when we provided the supports we did, we modified the statement to read:

There are supports specific to Horatio's needs that he requires to successfully engage with CT activities, and, when provided, these supports were sufficient for him to meaningfully engage in CT activities.

To summarize how our explanation evolved, initially, we expected that CT-specific supports would be necessary for Horatio to meaningfully engage in CT activities. However, the observation and interview data we collected suggested that these supports were specific to Horatio rather than to the content area and that, if those supports could be identified and provided, Horatio might be more meaningfully engaged across all content areas. We revised our explanation and then, when we tried some basic supports, we found that Horatio was meaningfully engaged in CT activities, leading us to this final explanatory statement.

3.2. Deacon's story

Deacon loved to be on the computer. He was good at computing and even better at gaming, so each Wednesday, when his class spent 30–45 min in computing time, whenever the teacher was not looking, he and his friends would flip from the tab displaying *Code.org* or *Scratch* to a new tab displaying their favorite online game, *Minecraft*. They would play for as many seconds as possible before Mrs. Moore neared their desks, whispering about their progress and passing along tips for success to one another. Whenever Mrs. Moore came close, they would switch back to their computing tasks. Unfortunately for them, Mrs. Moore caught on rather quickly and assigned a "Coding Journal" to each student in the class.[40] Mrs. Moore's class hated that journal; one of the students even labeled the journal, "My Pointless Coding Journal."[41] Every Wednesday, when the computer cart arrived in the classroom and the students gleefully obtained their Chromebooks, Mrs. Moore would just as gleefully pass out those dreaded Coding Journals, reminding the class that they were responsible for recording their progress through the levels on *Code.org* or the tasks they completed in *Scratch* as well as anything else they wanted to remember about their work. If they made progress, they earned privileges, such getting to play a game on the computer.

3.2.1. The struggle

In spite of Mrs. Moore's plan to help keep her class on task through the use of the Coding Journals, Deacon was struggling. A loss of privileges later did not hold much weight for him when the prospect of playing *Minecraft* was at his fingertips. Both Mrs. Moore and his special education teacher, Mrs. Williams, perceived that his refusal to do work, follow directions, and his impulsivity were the biggest ways his disability impacted his performance at school.[42] Mrs. Moore instituted the Coding Journals prior to the first observation for this study, but Deacon still spent a majority of his time that day playing *Minecraft*, watching his peers play *Minecraft*, or talking about playing *Minecraft* with his classmates. Of the 37 min of the first observation, Deacon was looking at *Code.org* for a total of 6 min – 4 min watching his neighbor work and 2 min working on his own – all with Mrs. Moore's direct supervision (see "on task" for 2/12 in Fig. 2). The minute she stepped away, Deacon and his neighbor were right back to *Minecraft*. Even during the mini-lesson at the start of computing time, Deacon played *Minecraft*, stopping to listen as a classmate taught them how to solve a problem they had encountered the week before for only three of the 12 min in the lesson (see "some engagement" for 2/12 in Fig. 2). The next Wednesday, Mrs. Moore was in meetings and a substitute teacher was teaching the class. Deacon and a few of his classmates who shared his disregard for the Coding Journal were thrilled! They got to be on *Minecraft* for an uninterrupted 21 min (see "off task" for 2/19 in Fig. 2).

3.2.2. The breakthrough

Although spending 30 min on Wednesday afternoon playing *Minecraft* was just fine from Deacon's vantage point, Mrs. Moore and Mrs. Williams, of course, wanted to make sure he was spending his time engaged in the intended activities for this time so that he would learn CT skills. In addition, Deacon's education team felt that following directions and remaining on-task, especially with activities he did not want to do, were critical skills they wanted him to develop. They instituted a behavior intervention plan (BIP) to help him learn these skills.[43] The BIP included three supports: (1) daily behavior report – each day, Deacon started and ended his day with Mrs. Williams to review expectations for his behavior throughout the day and how to earn points toward a weekly reward[44]; (2) voluntary breaks – Deacon was allowed to take a break, following a specific set of procedures, whenever he needed time to recenter, calm down, or express frustration in an appropriate context[45]; (3) after-school make-up time – if Deacon did not complete an assigned activity because he was refusing to do the activity or spending too much time off-task, he had to stay after school and complete the task(s).[46] These supports were effective across the school day, as long as Mrs. Moore and Mrs. Williams kept finding novel and motivating weekly rewards for

[40] Interview Transcript, p. 10.
[41] Interview Transcript, p. 10.
[42] Interview Transcript, p. 3.
[43] Interview Transcript, p. 7.
[44] Interview Transcript, pp. 2, 6.
[45] Interview Transcript, p. 6.
[46] Interview Transcript, p. 7; Observation notes, 3/5/15.

earning his daily behavior report points[47] and consistently followed through on the established consequences for failing to stay on task during the school day (a challenge, since Mrs. Williams was giving up her own personal, non-contract time to stay after school and monitor his completion of the missed tasks).[47]

On Wednesday, March 5th, computing time started poorly. Deacon was in a bad mood and seemed frustrated that Mrs. Moore was closely monitoring his activity, preventing him from getting onto *Minecraft*. After several minutes of pouting, wandering around the classroom, and complaining – Deacon commented, “I hate coding.”[48] – Mrs. Moore reminded him that he would have to stay after school if he did not progress through some levels on *Code.org*. Then, she suggested a race, “Let's race to finish all the levels. You're already two levels ahead of me, but I'm pretty sure I can catch up. Loser buys the other the candy of their choice?” Mrs. Moore offered.[8] “How about a milkshake?” Deacon counteroffered.[49] Mrs. Moore laughed and said, “Well, I'll try to arrange that but it's hard because when I'm at school, I can't really leave.”[50]

> “Deal!” Deacon agreed. As Mrs. Moore moved on to the next group of students, Deacon raised his hands over his head and said, “I must win!” Turning to his computer, he set to work and did not stop until the class was instructed to return their computers to the cart.[50] For the first time, he spent more than half of the computing time actually coding.[50] Breakthrough!

The deal worked. For the remaining observations, Deacon remained on task for most, if not all, of the time during computing (see Fig. 2). During the last observation in Mrs. Moore's classroom (5/15/15), Deacon and his friend, Elsie, sat next to one another, their bodies hunched over, faces close to the screen where their animated math problem on *Scratch* was slowly coming to life. Deacon and Elsie were each engrossed in their own code, changing the script and running it, changing the script again and then, pleased with the results, showing their projects to one another. Every now and then, Elsie would ask Deacon how he got his sprite to do something or Deacon would peer over Elsie's shoulder to find the same background she had, and, for 4 min, the two friends discussed other things unrelated to coding. But, aside from those 4 min, Deacon spent the entire computing time on task and engaged in coding and collaborating with Elsie about their *Scratch* project.[51]

As Mrs. Williams stated, “I think … Deacon takes a while to adjust to the [routine and expectations of] things.”[52] With Mrs. Moore's clear, consistent expectations and her ingenious use of the supports that had been successful in other areas of the school day (i.e., motivating rewards for completing assignments, consequences for off-task behavior), she supported a complete turn-around for Deacon. Gone were the days of frustration and complaining or playing *Minecraft* and sneakily switching between tabs to avoid Mrs. Moore's consequences. Instead, Deacon spent his time flying through the levels on *Code.org*,[53] creating animated math problems on *Scratch*[54] and collaborating with his peers about assigned tasks.[55]

Our observation of Deacon's experience was that he spent very little time engaged in CT instructional activities until Mrs. Moore initiated supports on March 5th (see Fig. 2). Our conversations with Mrs. Moore and Mrs. Williams confirmed this observation and they explained that these supports were successful in helping Deacon engage in instructional activities across the school content areas. Given that Deacon was successfully engaged in CT activities after that, we did not feel there was sufficient support for our original theoretical statement (i.e., *Students with disabilities require CT-specific supports to successfully engage with instructional CT activities, and when these supports are not available, students with disabilities cannot meaningfully engage in those activities*) in these data. Therefore, we modified our theoretical statement to explain Deacon's experience as follows:

> *There are supports specific to Deacon's needs that he requires to successfully engage with instructional activities, and, when provided, these supports are sufficient for him to meaningfully engage in instructional activities.*

4. Discussion

When we began this case study, we expected to find an array of supports specific to CT that schools would need to put into place to facilitate engagement for students with disabilities, and we based our initial theoretical explanatory statement on this. For example, we imagined that we would need to create visual supports for CT lessons or develop supplemental lesson plans with additional explicit instruction for CT concepts. Our experience with Horatio and Deacon contraindicated that explanation. Instead, in both cases, supports unique to the individual student were key to their full engagement in the CT tasks assigned to their class. Neither student required supports that were unique to computing alone but were instead successful in CT when supports they needed across their school day were provided during CT instruction and activities. Using

[47] Interview Transcript, pp. 2, 6.
[48] Observation notes, 3/5/15.
[49] Interview Transcript, p. 4.
[50] Interview Transcript, p. 4; Observation notes, 2/12, 2/19, 3/5.
[51] Observation notes, 5/14/15.
[52] Interview Transcript, p. 12.
[53] Interview Transcript, p. 4; Observation notes, 4/23, 4/30, 5/14.
[54] Observation notes, 4/23, 4/30, 5/14.
[55] Interview Transcript, p. 5; Observation notes, 4/23, 4/30, 5/14.

the same procedures we used to develop the within-case explanations, we took these findings and developed a cross-case assertion.

4.1. Cross-case analysis

We compared the explanatory statements we developed for Deacon and Horatio and the data sources from both cases to develop an assertion that accounted for both of these students' unique experiences in CT:

> If a student is struggling in CT, then first ensure that their student-specific supports are in place during CT instruction and activities. If the student continues to struggle, then explore additional CT-specific supports to incorporate into the pedagogy.

Fig. 3 displays the evolution of the within-case explanatory statements and our cross-case assertion, and we describe our cross-case assertion here.

As we compared the two within-case explanations, we returned to three premises, reviewed in the introduction, that were critical to understanding these students' experiences. First, content-specific supports are (or should be) encompassed in universally-designed pedagogy (Basham, Israel, Graden, Poth, & Winston, 2010; CAST, 2011). Second, universally designed CT pedagogy is only emerging in K-12 (Grover & Pea, 2013; Israel, Pearson, et al., 2015), and, therefore, content-specific supports may still be missing. Had our original explanatory statement been supported and content-specific supports identified for Horatio and Deacon, these supports could have been incorporated into universally designed CT pedagogy. However, the third premise we considered was as follows: for some students with disabilities, student-specific supports are necessary in addition to universally-designed pedagogy, and should be applied as needed across content areas (Thompson et al., 2009). In both case studies, we found that the existing content-specific supports within the Kranston CT curriculum plus student-specific supports were necessary for Horatio's and Deacon's increased participation in CT activities. That is, when Horatio was given complete access to his computer along with verbal explanations and models of the computing task, and when Deacon was given incentives to stay on task, both students shifted from minimal to prolonged engagement in CT activities. These supports were not unique to CT but were supports that the students needed across content areas.

Because content-specific supports should be encompassed into universally-designed pedagogy (Premise 1) and because CT pedagogy is still developing (Premise 2), educators must determine if students are struggling due to yet-to-be-developed pedagogical practices or to support needs specific to their disability. From our experience with these two cases, we believe that it is logical to begin by proactively planning for learner diversity within the general CT-instruction by incorporating features of UDL (Israel, Wherfel, et al., 2015). When this is in place, the next step is ensuring that students with disabilities receive their student-specific supports that are effective in other content areas (e.g., math, science) during CT instruction and activities as necessary. Then, if the student continues to struggle, the educational team can explore additional CT-specific

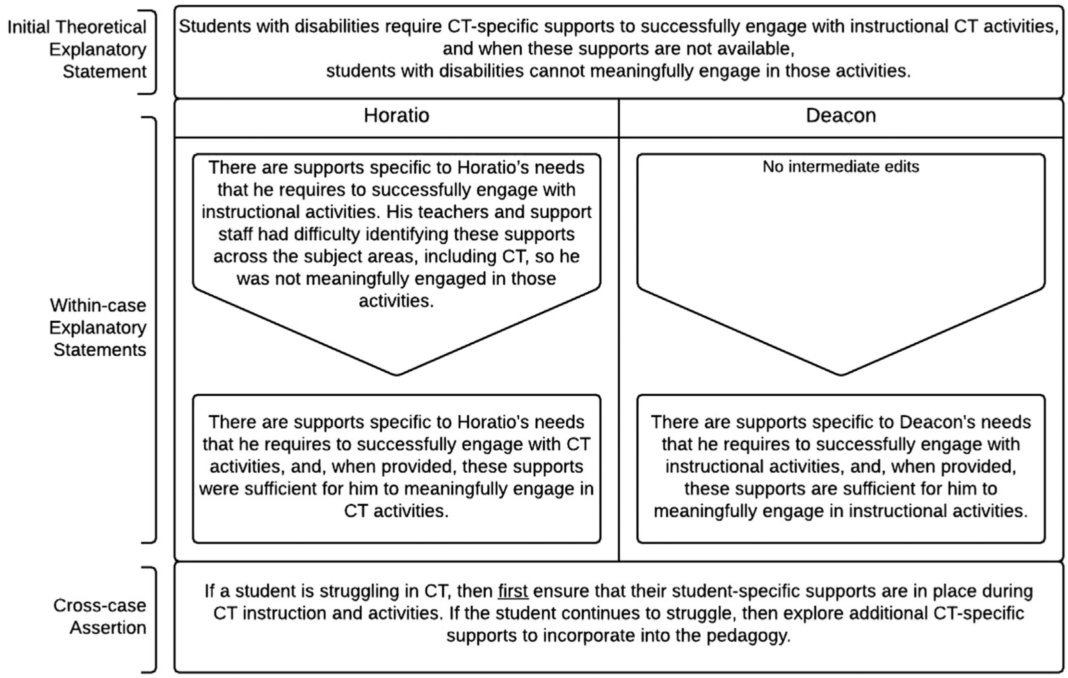

Fig. 3. The evolution of the explanatory statements of the within-case analysis and the cross-case assertion developed from these two cases.

supports that may need to be incorporated into K-12 CT pedagogy. Hence, our cross-case assertion is a model for evaluating and refining CT instruction, displayed in Fig. 4. This model highlights the need to evaluate both CT pedagogical approaches and individual support needs to ensure full participation of all students. With this approach, therefore, we are purposefully implying that all students, regardless of ability, have a right to participate in CT instruction, and that, if a student is not experiencing success, it is either the lack of appropriate student-specific supports or the current state of CT pedagogy that are disabling, as disability is defined as a mismatch between the demands of the environment and an individual's personal competency (Thompson et al., 2009).

4.2. A note about the teachers' experiences

As we have established, teachers who are providing CT instruction are applying a still-developing pedagogy. This is, of course, challenging, but CT poses an additional challenge to teachers. Consistent with previous research (e.g., Israel, Pearson et al., 2015), all the adults who participated in these case studies expressed concerns about their own limited CT skills and about how this influenced their ability to facilitate student learning. In addition, when the two students in our case studies failed to fully engage in CT instruction, the educators worried that their personal lack of competence in CT could account for these students’ struggles. However, when the teachers applied student-specific supports that were useful in other content areas, we observed all students, including those with disabilities, engaged in CT instruction and activities in their classrooms. Thus, although other content-specific supports may come to light as the school works toward integrating CT into their curriculum, these teachers discovered that, to date, their pedagogy was sufficiently universally designed to allow all students to participate once their individual support needs were met. We believe these teachers demonstrated the value of embedding pedagogy development into applied practice. Their expertise in supporting learning helped reveal the findings about supporting students with disabilities that we present here while still allowing the current generation of elementary school students to learn CT skills.

4.3. Caveats

We used Horatio's and Deacon's experience to develop our cross-case assertion but there are two important caveats to this. First, both Deacon and Horatio required relatively straightforward supports to experience CT success, but this will not be the case for all students with disabilities. Some students with disabilities require significant and complex supports to understand content and develop skills across the educational curriculum. Students who require modified performance expectations and complex supports to understand content in social studies and mathematics, for example, will likely require modified performance expectations and complex supports to understand content within CT instruction. Thus, translating student-specific supports into CT may prove challenging for some students, but this work is critical to ensuring students' full participation and success.

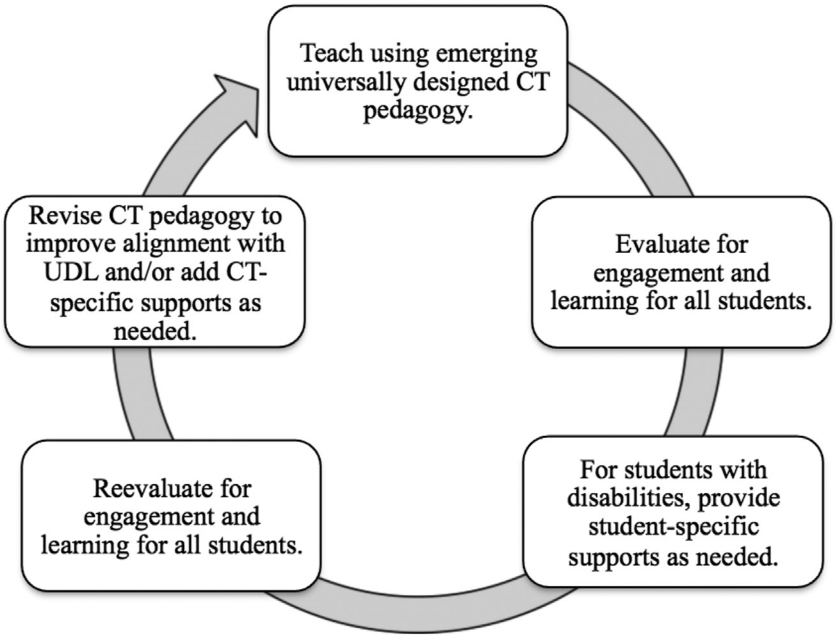

Fig. 4. CT instruction evaluation and refinement framework.

Second, by distinguishing between universally designed content-specific supports and student-specific supports, we do not mean to imply that content is irrelevant. Rather, we emphasize that individuals with disabilities have individualized support needs that likely require the commensurate supports be applied within each content area. For example, if a child requires modified material presentation in reading (e.g., use of text-to-speech technology to accompany text materials), the same modified material presentation support will look different in CT (e.g., screen reader within *Scratch* or *Code.org*), but it is modified material presentation that is needed in both settings. In another example, if a student requires manipulatives to understand abstract mathematical concepts such as fractions, that student might require manipulatives to understand the abstract spatial reasoning required to complete computing tasks (see, for example, Computer Science Unplugged activities at http://csunplugged.org/). Thus, identifying individual support needs and applying effective supports across content areas as needed is critical to the full participation of students with disabilities.

4.4. Implications for practice

We see four implications of this work for educators implementing CT instruction.

First, include students with disabilities in CT instruction. The two students we included in our case studies had very different disabilities but both successfully engaged in computing with supports tailored to their specific needs. Simply put, there is no reason to exclude students with disabilities from K-12 CT experiences. Rather, it is best to begin with the expectation for inclusion and consider how supports can increase engagement if the students are not finding initial success.

Second, use the supports that have been identified in other content areas when engaging in CT instruction. In our case studies, we found no evidence of CT-specific supports (outside of CT pedagogy) that the students with disabilities needed. The supports they needed across the school day were sufficient for success in CT activities.

Third, fight the urge to over-support or overcomplicate the provision of supports. With repeated access to unnecessary supports (e.g., one-on-one adult support, modified expectations), many students develop learned helplessness, or the unnecessary dependence on the help of others (Causton-Theoharis, 2009; Giangreco, Yuan, McKenzie, Cameron, & Fialka, 2005). Over time, receiving unnecessary supports can also erode a child's sense of self-determination (Stoner, Angell, House, & Goins, 2006). As Horatio's teachers discovered, starting with the simplest support – access to the computer – and gradually increasing the complexity of the support helped them identify the “just-right” amount of support. As always, presume competence in each student and support only when a demonstrated need appears.

Fourth, do not let your perceptions of your own lack of proficiency in CT discourage you from teaching it to all students. In both cases we examined, the teachers all expressed insecurity about their proficiency with computing, particularly with coding. While learning these skills are important to developing strong pedagogy over time, we found that the teachers were able to successfully support all students, with and without disabilities, in developing CT skills as the teachers were learning these skills too.

4.5. Limitations and implications for future research

This study critically examined the computing experiences of two students with disabilities who were initially disengaged during computing activities. Although our hypothesis shifted away from focusing on CT-specific supports, future studies should further unpack these findings. First, because this study only examined two students, we cannot assume that these findings will generalize to other contexts. Replication of this study would further support whether these findings generalize across students and contexts. Second, this study identified individual supports that resulted in increased engagement. These individual supports should be further studied using multiple methodologies to provide teachers with recommended practices that could help support students with disabilities during CT instruction. For example, Horatio required modeling, verbalizing problem solving, and access to the computer to fully engage in the CT activities. Although these supports are not unique to CT, it would be important to study further how these individual supports result in increased learning and engagement through additional methodologies, such as single-case design. Third, given the disproportionately low representation of people with disabilities in computing fields (Burgstahler & Ladner, 2007; NSF, 2015), future research should also focus on how the skills learned through CT instruction could contribute to the development of employment outcomes for students with disabilities. For example, both Horatio and Deacon showed a proclivity towards using computers. Once they become engaged in CT, those skills could be taught in a manner that could support functional career options such as computer programming and data analysis. This relationship between CT instruction and the actual skills that could contribute to the career development of students with disabilities should be further investigated.

Next, although we made a distinction between individual supports and universally designed content pedagogy, these two constructs are related. This relationship should be studied to refine emerging CT pedagogies to address the needs of students with disabilities. For example, there is a growing body of literature that suggests that proactively planning for learner differences through the UDL framework (CAST, 2011) and balancing explicit instruction (e.g., Archer & Hughes, 2011) with open computing exploration could meet the needs of a broader range of learners. These pedagogical practices have not been sufficiently studied within the context of K-12 computing, although there is promising research in transition to higher education computing programs (e.g., Burgstahler et al., 2012). Because these pedagogical practices have shown promise for supporting students with disabilities in other instructional areas, research on how to teach CT within the context of both UDL and embedding explicit instruction into open activities should be studied. Lastly, although research related to computer science instructional pedagogies in higher education is also still emerging, these practices should be investigated within K-12. These practices, such as peer instruction, the use of worked examples, and subgoal labels (e.g., Margulieux, Guzdial, & Catrambone, 2012; Morrison et al., 2015) may have implications for K-12 CT instruction. Future research should, therefore, also investigate these instructional approaches within K-12 and with diverse learners.

5. Conclusions

This paper examined the support needs of students with disabilities who initially were not engaged in computing instruction. Findings were consistent with other research that elucidated the need to provide individualized instruction to students with disabilities and that these individual supports help students with disabilities succeed academically. In this study, the supports that promoted access and engagement were student-specific rather than CT-specific. This finding was encouraging as it suggests that, although K-12 computer science and CT pedagogies are still emerging, teachers could use their professional judgment related to how to support students with disabilities in other content areas (e.g., reading, mathematics) within the context of computing instruction. Thus, finding effective supports required knowing the individual support needs of students and, when applied in CT, were feasible and effective even though the teachers were still developing their understanding of CT pedagogy.

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