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Utilizing a Computational Thinking Engagement Inventory to Support Inclusive Computational Thinking Pathways

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Utilizing a Computational Thinking Engagement Inventory to Support Inclusive Computational Thinking Pathways

Based in a research-practice partnership around district-wide computational thinking (CT) Pathways, this paper explores how six districts utilized the CT Engagement Inventory to examine if and how students are engaged in computing learning opportunities and write inclusive CT pathway goals. We found the CT Engagement Inventory supported districts in articulating inclusive pathway goals that moved beyond focusing only on access and participation. Instead, goals focused on building capacity to make broader access and participation possible and examining the nature of student participation. This paper demonstrates a tool to support districts in ensuring inclusive computing learning opportunities reach all students.

Keywords: computational thinking; engagement inventory; equity audit; K-12; CT pathways; research-practice partnership

Introduction

Within the K-12 computing education community, there has been decades of work toward creating more inclusive computational thinking (CT) and computer science (CS) learning opportunities. Initiatives have focused on broadening participation in computing and countering the marginalization faced by historically and systematically excluded learners (e.g., Goode & Margolis, 2011; Ottenbriet-Leftwich et al., 2022; Pinkard et al., 2017). Yet, many such initiatives have focused on extracurricular, classroom, or state level work. In this piece, we take a district-level perspective toward broadening participation in computing and ensuring all students have CT and CS learning experiences through what we refer to as “CT pathways”, or district-wide K-12 initiatives that are consistent across classrooms, cumulative from year to year, complementary

to subject-area learning, and competency-based (Authors, 2022). But, districts need support to develop pathways that are inclusive of all students and ensure not only access to, but participation in, and positive experiences of CT and CS. For districts to develop inclusive CT pathways, they need a clear understanding of the existing computing landscape within their district including who is currently enrolled in courses and the pedagogical strategies used across learning experiences. Specifically, supporting a district to consider its capacity for providing equitable, high-quality, meaningful CT and CS learning experiences and students' access to, participation in and experience of these CT and CS experiences as guided by the CAPE Framework (Fletcher & Warner, 2021) is essential for broadening participation in computing.

We partner with districts from across the United States through a research-practice partnership (RPP) focused on developing inclusive CT pathways. Together we co-create resources districts use within their own work and that can be shared across our network of districts. Collaboratively with one of our partner districts, we developed the Computational Thinking Engagement Inventory to support districts to examine current computing opportunities and write inclusive pathway goals for the year. The CT Engagement Inventory supports districts to identify needs within their schools to promote the development and maintenance of not just a CT pathway, but an *inclusive* CT pathway.

In this paper, we present the CT Engagement Inventory and results from six districts using the tool. Specifically, we show how the districts used the CT Engagement Inventory to learn about computing offerings within their district and to develop inclusive pathway goals for their pathway initiative. We answer the research questions:

1. How do district leaders utilize a CT engagement inventory to analyze data about capacity for, access to, participation in, and experience of computing learning experiences within their districts?
2. How, if at all, does a CT engagement inventory support district leaders to write actionable inclusive pathway goals?

This work presents one tool for districts to use as they build inclusive CT pathways that ensure high-quality computing learning opportunities for all students and builds on nascent research around developing equitable computing initiatives from the district-level. It provides a deeper understanding of how tools focused on assessing student engagement and inclusion can be used within computing initiatives to work toward broadening participation in CS for all students.

Background

Creating equitable learning opportunities for students has been a goal of the CS education community for decades. Previously, discrepancies have been identified in how technology is used in classrooms of predominantly white students compared to how technology is used in classrooms largely made up of students of color. Research has shown white students are exposed to more open-ended, creative tasks and students of color use technology primarily for skill-based, repetitive exercises (Warschauer, 2000; Wenglinsky, 1998). Similar inequities have been shown within CS learning opportunities (Margolis et al., 2008). In addition to disparities in computing learning opportunities for students of color, female and non-binary students as well as students with disabilities also continue to be marginalized in and excluded from these courses (Code.org et al., 2023). While some gains have been made in access to and participation in courses (Code.org et al., 2023), there is still a need to increase participation in these courses and

ensure students from non-dominant groups have robust and meaningful computing learning experiences.

There are many efforts underway to address the current discrepancies in who takes and who finds success in computing. Within the U.S., funding agencies have invested heavily in broadening participation in CS in particular (Marshall & Grooms, 2022). This mantel has been picked up through the design of courses, state-wide efforts, and out-of-school programs specifically for students who are marginalized and excluded from computing spaces (e.g., Goode & Margolis, 2011; Pinkard et al., 2017). Efforts at the state level to increase and broaden participation have mainly focused on increasing course offerings, ensuring more teachers are qualified to teach CS, and developing metrics and systems to accurately assess access to CS courses (Goldsmith & Stanton, 2021; Dunton et al., 2022). As more courses become available to students, curriculum efforts have been underway to ensure that participation in these courses furthers opportunities for students historically excluded from computing spaces. One such example is the development of *Exploring Computer Science*, a college-preparatory CS course that is designed to broaden participation in CS by making CS accessible to students who have little prior experience in CS and provide computing activities that are responsive to students' interests and identities (Goode & Margolis, 2011). In addition to curricular efforts, programs such as *Digital Youth Divas* (Pinkard et al., 2017) and *COMPUGIRLS* (Scott & White, 2013) were designed as out-of-school opportunities for female students from non-dominant cultures to explore computing while being responsive to injustices in their communities, areas of personal interest, and stereotypes about who does and doesn't belong in computing fields.

Additionally, the integration of CT into disciplinary classes has been touted as an opportunity to ensure more students, and a diverse group of students, have access to computing

learning opportunities (Mills et al., 2021). To make these computing learning opportunities more accessible to all students, some focus has been placed on support and initiatives from the district-level. These district-level initiatives can ensure computing is not something that is only in a select group of classes and can seek to counter trends of computing learning opportunities differing based on school characteristics within a district, particularly when they take a data-centric approach to examining and finding the root causes of inequities (Phelps & Santo, 2022). While these district efforts to integrate CT K-12 have been understudied, research has found challenges with this approach. In a small school district in California, Proctor and colleagues (2019) found there was a lack of agreement among the committee charged with developing their K-12 computing program regarding whether to emphasize broadening access to computing education or to focus on strengthening the competencies of students in computing courses. Similarly, efforts to expand access to computing in a small district in the Northeast met with resistance from leadership when seeking to provide professional development that would support the integration of CT into content area courses (Santo et al., 2020). The challenges in these districts suggest that district-led efforts to broaden participation in CS may benefit from processes, routines, and tools to support a more systematic approach.

Such tools have been researched, but little has been done in computing contexts. For example, equity audits harness school-level and district-level data to understand gaps and identify challenges in access (Dodman et al., 2019). In K-12 education, equity audits have been used to understand problems of practice contributing to achievement gaps, particularly affecting students in populations that have been historically marginalized or excluded (Skrla et al., 2004; Palmer et al., 2019). Equity audit tools focus on various components, but commonly look at teacher quality data, educational programs or current offerings, and student achievement or

participation (Skrla, et al., 2004). Equity frameworks emphasize the importance of utilizing data to understand participation. When districts disaggregate data by student group, it allows them to understand access across all student groups and discuss key outcomes or differences (Squires & Roberts, 2021). These tools engage educators in identifying patterns of inequity, identify potential causes, and begin identifying strategies for change (Capper et al., 2020; McKenzie & Skrla, 2011).

To date, research on broadening participation in CS education has focused on state, local, or district-level systems and policies changes enacted to increase student participation in K-12 CS opportunities (Ottenbriet-Leftwich et al., 2022; Phelps & Santo, 2022). Findings indicate that while gains have been made in schools offering CS courses, gaps remain in ensuring that student experiences in computing experiences are inclusive, accessible, and culturally relevant (Kapor Center, 2021). While equity audits have been used in other parts of education, the use of an equity audit to support district-level computing work with the aim of increasing inclusive computing learning opportunities is understudied. This work presents such an instrument and examines how it was used within six districts.

Theoretical Framework

Our work is guided by the CAPE Framework, a theoretical framework designed to assess equity across an entire CS ecosystem. The acronym CAPE highlights the four inter-connected and cumulative key components the framework addresses: Capacity for, Access to, Participation in, and Experience of equitable CS learning opportunities (Fletcher & Warner, 2021). Through the use of the CAPE framework, initiatives focus attention across equity needs related to capacity, access, participation, and engagement, rather than focusing on a single component or an end goal. Within CAPE, capacity encompasses the resources and support needed to create and

maintain CS learning opportunities (Fletcher & Warner, 2021). This includes community support, curriculum, funding, policies, and professional development (McGill et al., 2023). Within K-12 education, access typically means attending a school that offers CS learning opportunities (Fletcher & Warner, 2021), including curriculum offerings and extracurricular activities (Gransbury et al., 2023). Participation in CS education is measured by enrollment in CS learning opportunities offered at a school (Fletcher & Warner, 2021), either a course or extracurricular activity (Gransbury et al., 2023). Finally, experience of CS education pertains to outcomes and engagement within CS learning opportunities (e.g., whether learning experiences are inclusive and personally relevant, whether students are successful academically; Fletcher & Warner, 2021). Employing the CAPE framework in the analysis of district goals can help to more clearly align district equity goals with districts' CS initiatives and programs (Adrion et al., 2022; Cobo et al., 2024). Previous research has utilized the CAPE framework at the district level to explore root causes of inequity within district-wide computing initiatives and highlight the factors that led to those inequities (Phelps & Santo, 2022). Use of the CAPE framework can encourage districts to focus on the multidimensionality of seeking to broaden participation in CS learning experiences and to identify problems in the systems of the school district, not with the students (Phelps & Santo, 2022). Building on this prior research, we utilize the CAPE framework to guide our analysis of districts' utilization of the CT Engagement Inventory and their resulting inclusive pathway goals.

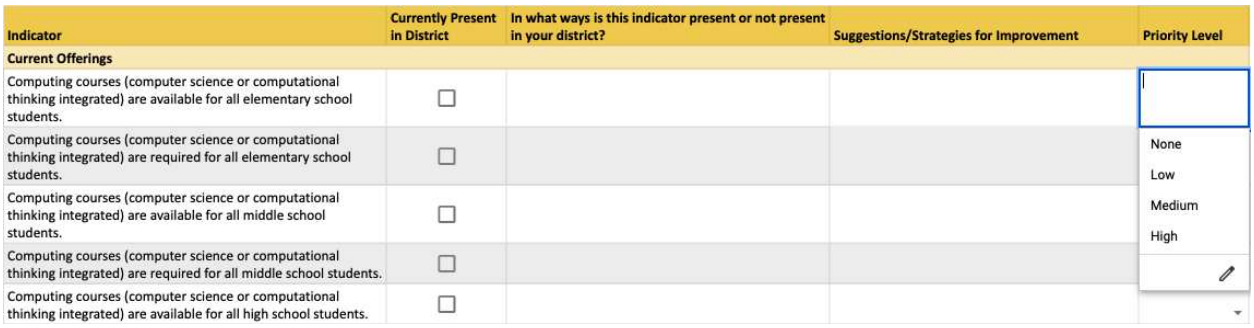
Methods

The CT Engagement Inventory

The CT Engagement Inventory (Table 1; Figure 1) was created as an "equity audit" that supports districts to center inclusive practices within their CT and CS work. It was designed to

be completed by district leaders or internal district committees focused on developing CT pathways. The CT Engagement Inventory is intended to be repeated to allow districts to note areas of growth and identify new areas of need as their initiative progresses. The CT Engagement Inventory was co-designed with one of our district partners, Cardinal Valley School District, during a larger co-design effort to create resources for districts who were developing CT pathways. The idea of developing an inventory to support districts to assess the inclusivity of their existing computing offerings originated from within the research-side partners, but was supported by Cardinal Valley and the idea led to conversations about the content and design of such a tool.

Figure 1. Sample of Version A of the CT Engagement Inventory



Indicator	Currently Present in District	In what ways is this indicator present or not present in your district?	Suggestions/Strategies for Improvement	Priority Level
Current Offerings				
Computing courses (computer science or computational thinking integrated) are available for all elementary school students.	☐			
Computing courses (computer science or computational thinking integrated) are required for all elementary school students.	☐			
Computing courses (computer science or computational thinking integrated) are available for all middle school students.	☐			
Computing courses (computer science or computational thinking integrated) are required for all middle school students.	☐			
Computing courses (computer science or computational thinking integrated) are available for all high school students.	☐			

Version A of the CT Engagement Inventory (the version used within this research) has 28 indicators (Table 1), for example, *"Computing courses (computer science or computational thinking integrated) connect with family and community members to incorporate their perspectives into computing activities."* The indicators are split into four categories: current offerings (13 indicators); designing accessible instruction (5 indicators); connecting to students' interests, homes, and communities (4 indicators); and acknowledging and combating inequity (6 indicators). For each indicator, those completing the inventory mark whether or not that indicator

is currently present in their district and take notes about the ways the indicator is or is not present and any suggestions or strategies for improvement. After reviewing all of the indicators and whether they were present in their districts, those completing the inventory can use the drop down in the "priority level" column (none, low, medium, high) to mark the indicators they want to focus on initially (Figure 1). At the suggestion of Cardinal Valley, the majority of the indicators align to the research-based inclusive computing practices in Authors (2021). Further, the overall structure of the CT Engagement Inventory is based on the TEC Rubric, a tool designed to evaluate CS curricula to determine if they are effective and equitable (Weintrop et al., 2019).

Table 1. Equity Indicators on Version A of the CT Engagement Inventory

Current Offerings
Computing courses (computer science or computational thinking integrated) are available for all elementary school students.
Computing courses (computer science or computational thinking integrated) are required for all elementary school students.
Computing courses (computer science or computational thinking integrated) are available for all middle school students.
Computing courses (computer science or computational thinking integrated) are required for all middle school students.
Computing courses (computer science or computational thinking integrated) are available for all high school students.
Computing courses (computer science or computational thinking integrated) are required for all high school students.
Students can fulfill graduation requirements with computing courses.
The percentage of students in computing courses who identify as girls or gender non-binary is equal to or greater than the percentage of girls and gender non-binary students in our entire student body.
The percentage of students in computing courses who identify as Black or African American, Latinx/Latine, Pacific Islander, or Indigenous is equal to or greater than the percentage of Black or African American, Latinx/Latine, Pacific Islander, or Indigenous students in our entire student body.
The percentage of students with disabilities in computing courses is equal to or greater than the percentage of students with disabilities in our entire student body.
In computing courses, the rate of course completion and final grades of students who identify as girls or gender non-binary is similar to or greater than the course average.

In computing courses, the rate of course completion and final grades of students who identify as Black or African American, Latinx/Latine, Pacific Islander, or Indigenous is similar to or greater than the course average.
In computing courses, the rate of course completion and final grades of students with disabilities is similar to or greater than the course average.
Designing Accessible Instruction
Computing courses (computer science or computational thinking integrated) utilize the principles of Universal Design for Learning and provide multiple means of engagement, representation, and action and expression, such as using a physical representation of code blocks to model computing or providing students with starter code.
Computing courses (computer science or computational thinking integrated) facilitate well-structured collaborative learning opportunities, such as pair programming and Process Oriented Guided Inquiry Learning (POGIL).
Computing courses (computer science or computational thinking integrated) make expectations explicit, such as providing a checklist for students to check their progress as they develop computational artifacts.
Computing courses (computer science or computational thinking integrated) normalize and encourage making mistakes, getting stuck and redoing activities when developing and refining computational products. One way to do this is through think-alouds where teachers (or students) say what they are thinking and doing when programming.
Computing courses (computer science or computational thinking integrated) provide students choices in their creation of computational artifacts by curating and modeling a variety of product outputs (e.g., interactive art, digital stories, e-textiles, video games, and simulations) that align with learning objectives.
Connecting to Students' Interests, Homes, and Communities
Computing courses (computer science or computational thinking integrated) give students the opportunity to develop and express their interests and experiences through computational thinking activities and computing tools.
Computing courses (computer science or computational thinking integrated) connect with family and community members to incorporate their perspectives into computing activities.
Computing courses (computer science or computational thinking integrated) promote linguistic pluralism in class and computing projects by encouraging translanguaging, allowing students to create projects in their language of choice, or utilizing the translated block options on Scratch.
Computing courses (computer science or computational thinking integrated) showcase students' work with technology related organizations in the community to connect, celebrate, and legitimize their expertise.
Acknowledging and Combating Inequity
Computing courses (computer science or computational thinking integrated) acknowledge power dynamics associated with race and representation in computing, such as the overrepresentation of white male computer scientists, and actively combat those power dynamics in the classroom (e.g. amplifying the voices of students experiencing marginalization).
Computing courses (computer science or computational thinking integrated) recruit students who experience exclusion from computing to computer science classes (e.g., Black or African American, Indigenous, Pacific Islander, and Latinx/Latine students; students with disabilities; girls; non-binary students).

Computing courses (computer science or computational thinking integrated) celebrate the multiple, overlapping identities of students experiencing marginalization and validate the unique perspectives they hold about technology.
Computing courses (computer science or computational thinking integrated) challenge stereotypes about who a computer scientist is and who belongs in the technology field, such as celebrating and giving examples of the work of people that have experienced marginalization based on race, gender, or ability.
Computing courses (computer science or computational thinking integrated) teach students about biases in technology, such as in algorithms and artificial intelligence.
Computing courses (computer science or computational thinking integrated) provide opportunities for students to speak about and improve injustices through computational means, such as creating an app, digital story, or game that showcases and counters inequities.

Participating Districts

Six school districts in the United States utilized the CT Engagement Inventory as part of a four year, federally funded RPP to develop and scale inclusive CT pathways. Our analyses focus on the completed inventories from the six districts: Bearhill School District, Cardinal Valley School District, Coyote Hills School District, Elkville School District, Fox Bluff School District, and Turtle Creek School District. Three districts have been engaged in ongoing work to build CT pathways with the research team since 2017 and the other three have been engaging in the work collaboratively for 2-3 years (although some districts have had computing initiatives for longer). Districts participating in the RPP vary by urbanity (1 urban, 4 suburban, 1 rural), size (2 <5,000 students; 1 5,000-10,000 students; 1 10,000-20,000 students, 1 20,000-30,000 students; 1 >200,000 students), location (midwest, northeast, southeast), and student population. Districts serve students from a wide range of demographic backgrounds (35-88% White, 1-40% Black, 2-40% Hispanic or Latinx, 0-36% Asian, 3-6% multi-racial, 1-14% English Language Learners, 11-16% students with disabilities, 12-70% students experiencing economic disadvantage or on free or reduced lunch.

Data Collection

The six district teams first engaged district leaders with the CT Engagement Inventory in November 2022. District leaders (generally a subgroup of the team that completed the full CT Engagement Inventory) walked through the CT Engagement Inventory with research-side partners at an in-person convening. To ensure district leaders had the information they would need to begin the CT Engagement Inventory, they were asked to bring district-level data on courses, course completion, and student demographics to the convening. After meeting with the research team in person, district leaders were asked to meet with their CT leadership teams to complete the CT Engagement Inventory, identify their top priorities, and identify a district inclusive pathway goal based on the findings from the exercise. Each district completed the inventory following the in-person convening.

Researchers collected completed CT Engagement Inventories from district leaders following their completion in Spring 2023. Researchers conducted interviews with district leaders in Summer 2023 to understand the process districts used to complete the CT Engagement Inventory, why they prioritized certain items, their process of moving their CT Engagement Inventory towards an inclusive pathway goal(s), and how their goals may have evolved from previous goals. Interviews followed a semi-structured interview protocol, lasted between 15 and 22 minutes, and were conducted during regular one-on-one meetings between members of the research team and district leaders. All interviews were recorded and transcribed.

Data Analysis

To analyze the collected data, first, two researchers reviewed the completed district CT Engagement Inventories and used analytic memos to make note of trends across the six districts. The two researchers have been active research-side partners in the RPP, which involved meeting with district partners on a monthly basis, conducting ongoing research, and providing support on

individual district needs. One researcher led the co-design of the CT Engagement Inventory (Version A) with Cardinal Valley School District and both researchers were involved in updating the tool to align to the CAPE Framework (Version B). The two researchers collaboratively added to the analytic memo and met to discuss the trends as they emerged. This analysis supported the development of the interview protocol for the district interviews.

Following the interviews, one researcher developed a codebook based on inductive open coding and deductive codes from our theoretical framework and the interview protocol. The codebook included codes related to the interview questions, CAPE framework, and the CT Engagement Inventory tool itself. Coding categories included codes related to the interview questions (e.g., getting and using data, transition Inventory to goals), codes related to the CAPE Framework (e.g., Capacity, Access), and codes related to the Inventory tool itself (e.g., celebrations (positive feedback), challenges (places for improvement)). The two researchers coded each district's interview using the codebook. To ensure reliability, the researchers met to discuss their coding results, resolve any coding disagreements, and determine final codes for all interviews.

The same two researchers coded each district's 2023-2024 inclusive pathway goals using a codebook based on the CAPE framework and the extended CAPE framework (Fletcher & Warner, 2021; McGill et al., 2023) at the component and subcomponent level (e.g., Capacity: Curriculum). The two researchers coded the inclusive pathway goals separately and met to reach 100% agreement on all codes. Notably within the coding process there was a question over the coding of the use of inclusive pedagogies. While the extended CAPE framework, lists "Culturally-relevant/responsive pedagogy" under the component "Capacity: Curriculum", the researchers interpreted this as "capacity" when pertaining to teacher's knowledge and having

curriculum to use these inclusive pedagogies, but culturally and personally relevant learning opportunities as "experience" in alignment with original CAPE framework (Fletcher & Warner, 2021).

Finally, the researchers collaborated to align Version A of the CT Engagement Inventory to the CAPE framework using the same codebook as was used on the district inclusive pathway goals.

Results

District Leaders' Utilization of the CT Engagement Inventory

In this section, we utilize data from the districts' completed CT Engagement Inventories and district leader interviews to answer the research question: *How do district leaders utilize a CT engagement inventory to analyze data about capacity for, access to, participation in, and experience of computing learning experiences within their districts?*. We found that across all six districts, it was necessary for the practice-side RPP leaders to bring in other voices to complete their CT Engagement Inventory, particularly to gather qualitative data about courses. When completing the CT Engagement Inventory and in interviews, district leaders were most focused on capacity for computing and were least focused on experiences participating in computing learning opportunities.

In all six districts, at least one of the district leaders who works directly in our RPP led the completion of the CT Engagement Inventory, at times in consultation with their broader CT pathway committee. In addition, the RPP practice-side leaders often brought in other district leaders, school leaders, and/or teachers to support the completion of the inventory. This included consulting the instructional technology team, a district staff member in charge of data, high school CS teachers, curriculum directors, and the district Executive Director of Equity.

Consulting these additional individuals served multiple purposes. In most school districts, it provided additional expertise. As one district leader in Elkville School District shared,

> We [the district leaders who started the Inventory] are both elementary…a bulk of our computer science classes are at the High School and some at the Middle School, and we felt like we weren't knowledgeable enough in that area to complete the [inventory] on our own. So we reached out to our district data person to pull [data] and…even talk[ed] to our high school computer science teachers to get their lens on it as well.

In Coyote Hills, the additional input served to check that the impressions of the district leaders were correct. When talking about who took part in completion of the CT Engagement Inventory, a district leader shared,

> We talked with…some of our curriculum directors. So, Director of Middle School Core Curriculum, Director of High School Core Curriculum. We also have a…newly titled Executive Director of Equity that we spoke with him…but again it, when we spoke with those individuals it just reaffirmed what we believed.

With the support of these additional staff members, district leaders were able to gather the data they needed to complete the CT Engagement Inventory.

Leaders across districts shared that they began their data collection efforts prior to the fall 2022 convening when the CT Engagement Inventory was introduced (as they were asked to by the research team). This data collection typically focused on collecting course data from district systems and learning what happens in courses. In some districts, the RPP leaders had ready access to the course data, while in others it needed to be accessed through a centralized district person in charge of data. For example, in Fox Bluff, a district leader was able to find a printed report of computing participation within the high school where he is principal on his desk and share it in the interview. In contrast, district leaders from Elkville discussed needing to contact

their district data lead to gain access. District leaders also discussed the importance of qualitative and anecdotal data from people who are on the ground. A Turtle Creek leader shared, “I think qualitative and quantitative data really come into play…It's easy to let somebody slip through the crack, and we don't want anybody to slip. So, making sure that we touch all those [data] points.”

Examining the district CT Engagement Inventory results, we found differences in whether indicators were present within a district based on the component of CAPE to which they aligned. While this finding is limited because the number of indicators align to each CAPE category differs, districts were more likely to mark an indicator as present within their district for the Capacity (100% of districts) and Access (89% of indicators by district) aligned indicators than for the Participation (40% of indicators by district) and Experience (60% of indicators by district) indicators. Additionally, in the district leader interviews, districts were most focused on capacity (45 utterances across 6 districts) followed by access (18 utterances across 6 districts) and participation (18 utterances across 5 districts). District leaders were least focused on experience (7 utterances across 3 districts).

We further examined the CT Engagement Inventory results to better understand the data that district leaders gathered and included in their inventory. In the explanation column of the CT Engagement Inventory, district leaders noted that indicators were met based on specific classes that are taught (e.g., integration through library media specialists), curriculum that they used (e.g., code.org; CodeHS) or learning spaces (e.g., Maker Spaces in Library Media Centers). Other district initiatives and ongoing work also played a role. For example, in Turtle Creek, the larger STEM initiative within their district and the community support around that initiative provides strong opportunities to meet indicators pertaining to connections to family and

community. In their explanations of indicators, districts also discussed how many of the indicators varied across the district based on school, grade level, or teacher experience.

Utilization of the CT Engagement Inventory to Write Actionable Inclusive Goals

In the following section, we use our analysis of the districts' CT Engagement Inventories, inclusive pathway goals (Table 2), and district leader interviews to answer the research question: *How, if at all, does a CT engagement inventory support district leaders to write actionable inclusive pathway goals?* As evidenced by this data, representation of students who experience marginalization and exclusion from computing opportunities remains a consistent challenge. However, across all six districts we found the CT Engagement Inventory supported district leaders to write actionable inclusive pathway goals. The use of the CT Engagement Inventory allowed districts to prioritize areas where they needed to push their pathway work forward, identify specific populations where participation was limited, whether by grade level or student demographics, and assess teacher capacity and student experience within computing experiences offered. Districts described that the CT Engagement Inventory moved them to develop inclusive pathway goals that were reflective of their current needs and priorities (Table 2). For example, in Turtle Creek, district leaders found that they were not reaching all students through their existing computing opportunities. One district leader said, "We look at the data of…who's enrolled in computer science classes and…we're just trying to reach all…Looking at what we're reaching, we weren't necessarily reaching all in all grade levels. So that's kind of our goal."

Table 2. District Inclusive Pathway Goals and Researcher Coding

District	Inclusive Pathway Goal (2023-2024)	CAPE Framework Coding
Bearhill School District	● Ensure broader representation of females and underrepresented groups, with a focus on elementary grade integration in social studies and science	● Capacity: Curriculum ● Access: Curriculum Offerings ● Participation: Course

		Enrollment/Participation
Cardinal Valley School District	• Implement more teacher training and additional resources to support integration across curricular areas • Consider exploring local partnerships to showcase and celebrate students' work. (i.e. hackathons, tech fairs, etc)	• Capacity: Human Resources • Capacity: Curriculum • Capacity: Community Environment, Culture, & Ideology Supporting CS Education Implementation • Experience: Student Engagement
Coyote Hills School District	• Analyze district recruiting efforts to reach students who historically have not enrolled in computing courses, with the goal of course enrollment being more reflective of district demographics • Provide students with intentional opportunities to explore interests and passions with CT and the opportunity to bring more choice, lived experiences, and voice, in the development of artifacts of learning that align with their interests	• Participation: Course Enrollment/Participation • Experience: Student Engagement
Elkville School District Kettle	• Coach teachers on intentionally incorporating CT into instruction and explicit instruction solving CT problems • Identify the broader district barriers for students with special needs, girls, and class conflicts and see what we can do	• Capacity: Instructional Strategy - Pedagogy / Pedagogical Approach • Capacity: Human Resources • Participation: Course Enrollment/Participation
Fox Bluff School District	• Scale K-12 integration of at least one CT practice across all grade bands • Continue district trajectory of broadening diverse student representation in CS courses	• Capacity: Curriculum • Access: Curriculum Offerings • Participation: Course Enrollment/Participation
Turtle Creek School District	• Increase access for all students	• Access: Curriculum Offerings

As is seen in Table 2, districts' inclusive pathway goals span all four components of CAPE, focusing on creating more inclusive capacity for (4 districts, 5 goals), access to (3 districts, 3 goals), participation in (4 districts, 4 goals), and experience of (2 districts, 2 goals) computing within the districts. While in early years of our work districts' inclusive pathway goals focused on expanding access and participation of a particular subgroup of students who

experienced marginalization and exclusion from computing (e.g., ELL students, students of color, girls), using the CT Engagement Inventory appears to have supported districts to write their inclusive pathway goals more expansively and focus on needs beyond access. District inclusive pathway goals moved beyond providing access towards more specific, actionable goals including understanding course recruitment efforts, providing targeted supports and culturally responsive curriculum, and focusing on grade level integration. In comparison to their previous goals, district leaders in Bearhill stated,

> I think we've made a lot of strides in that. And also looking at our students who are in poverty, we are really to the point now where we're serving more students who are in poverty than are not in some of these classes. So I do see that we've made a lot of improvements in those areas. Now, we're kind of looking at age group and really trying to make sure that kids, even as young as kindergarten are having those experiences, whether they're plugged or unplugged to have that computational thinking just embedded as early as possible, so that it's not a new thing for them when they get to our middle school.

While we did not have a direct point of comparison for districts who are newer to the CT pathways work, their goals followed the same patterns, focusing not only on access and participation, but also on building the capacity that enables growth in access and participation as well as student experience within computing learning opportunities.

In Coyote Hills School District, district leaders found they needed a partner to walk them through the process of moving from the CT Engagement Inventory to an inclusive pathway goal while balancing inclusive computing priorities with broader district equity work. The Coyote Hills team worked closely with a researcher to consider their district priorities, with one district leader noting,

> We have a lot of equity work that's happening in the district - a lot of really strong, positive equity work…so it's hard for us to isolate it and say, "okay, well, now, equity work just focused on CT." We want it to be overall global equity work across all of our classes and opportunities for all of our students. And so it was hard for us to go narrow on this and say it's just CT focused, or where do we want to focus from an equity lens? We did a lot of brainstorming with [researcher] and [they were] really helpful in the development of our goals. I think one of the…pieces that we wanted to do was we wanted our goals to be reflective of the district work that's happening. Again, from a larger network perspective, and just from a larger perspective in general. So we're doing a lot of work across the district with providing more voice, choice, and [researchers] helped us add that lived experience language that's in a lot of our conversations with our teachers and our students and in classrooms. And so that had a natural fit here. In those opportunities from a computational thinking perspective. How do we bring in that same idea?

While they still needed support, the CT Engagement Inventory supported district leaders in connecting conversations happening across their district to expanding computing opportunities for students and provided a framework for the district leaders to receive support from the project researchers.

Discussion

With much of the current focus within the field of computing education currently focusing at the classroom or policy level, research and tools to support inclusive computing initiatives at the district-level remains relatively nascent. Yet, existing research has highlighted a potential need for processes, routines, and tools to support systems-level work that impacts students across classrooms and schools (Proctor et al. 2019; Santo et al., 2020). Our work aims to add to this under researched area by presenting one tool for district leaders to examine the current scope of their computing initiative and set goals for developing an inclusive computing

pathway. Our findings demonstrate how district leaders can utilize tools, like the CT Engagement Inventory, to understand student participation and experience in computing and expand capacity for and access to computing opportunities. Building on previous work of utilizing equity audits to understand state, district, and school-level improvement efforts (McKenzie & Skrla, 2011; Palmer et al., 2019), our findings support ongoing research in supporting district and school leadership teams in assessing their current computing and CS learning experiences and measure progress toward their inclusive pathway goals.

Beyond building on prior work in equity audits and expanding this work into the field of computing education, we found alignment between our findings and prior research at the district level focused on assessing computing from the systems-level. This prior work highlighted the importance of district leaders being able to "analyze data for indicators of inequities" and "embeddedness in instructional networks" (Phelps & Santo, 2022). In bringing together educators and leaders from across their districts, examining quantitative and qualitative data, and examining the data looking specifically for equitable student engagement, the district leaders used the CT Engagement Inventory to do as Phelps and Santo suggest and, in agreement, spoke to the importance of these different voices and data types. Phelps and Santo (2022) further foreground the importance of district leaders conceptualizing "equity as a multifaceted phenomenon." The changes in districts' inclusive pathway goals demonstrate this very conceptualization, a change from before the leaders were introduced to the CT Engagement Inventory. Rather than seeing exclusion for computing pathways in their district as having a singular cause rooted in access or participation, district views of that exclusion expanded to include focus on capacity and experience.

Redesigning the CT Engagement Inventory

While Version A of the CT Engagement Inventory successfully supported district leaders to examine their current computing initiative and write inclusive pathway goals to direct their continued work, our analysis and interviews with the district leaders surfaced both areas of strength and areas of improvement for the tool with opportunities for enhancement to better support district leaders. For example, district leaders in Bearhill had positive feedback about the CT Engagement Inventory, emphasizing that it prompted district reflection and supported systematically examining existing efforts to consider next steps. District leaders in Cardinal Valley, who originally supported the co-design of the tool, also emphasized that the tool allowed for structured reflection and highlighted how it gave the team common language, saying,

> It's a great resource because it provides a common language for you to know what your…aspirational areas are, and then…being able to actually have ways to filter that further in regards to, is it currently present or not? And then having to actually reflect on, if you said, "Yeah, it's present." Well, then, where's it at? So, I think it's just an opportunity to certainly reflect in a very structured way.

For the Cardinal Valley team, the CT Engagement Inventory provided a meeting structure while still allowing flexibility not to focus on everything in one year, but rather to pinpoint priorities and revisit indicators as capacity arose.

District leaders also highlighted challenges in using the tool. One ongoing challenge in multiple districts is discussing equity in states where the political climate has decentralized and attacked such work in schools. We partnered with districts to ensure the CT Engagement Inventory worked towards inclusive computing for all students within the allowable confines of these districts. Further, reflecting on the tool specifically, district leaders cautioned that it was long and felt wordy in a way that could be overwhelming, especially for new districts. Leaders from Bearhill cautioned that for districts where most of the indicators were not yet met, the tool

could make the work to be done seem overwhelming. For the district leaders in Coyote Hills, the checkboxes used to denote whether an indicator was present or not felt perfunctory to them. They reflected,

> I like activities that I can take to other leaders and have them look at it, and potentially come up with a different result or have a different perspective. This was very black and white, like, yes, no, yes, no…and it just felt very narrow in its focus, and I think because of the narrowness it was hard to formulate a conclusion or a next step from it.

They also shared that many of the indicators felt like they went beyond what could be changed at the level of a CT pathway and were larger systemic changes beyond their decision-making power.

Following the interviews with district leaders and receiving this feedback, the research team revised Version A of the CT Engagement Inventory to make iterative changes that would best support the district leaders using the tool. In Version B of the CT Engagement Inventory, the research team moved away from any direct use of the term "equity", including having originally referred to the CT Engagement Inventory as an equity audit. Additionally, we aligned the CT Engagement Inventory to the CAPE framework (Fletcher & Warner, 2021) to emphasize equitable engagement not only in classroom experiences, as version A emphasized with the use of the inclusive pedagogies as indicators, but also the groundwork in capacity that is required (and where districts newer to the pathway creation process will likely need to begin). In the alignment process, we worked to even the number of indicators pertaining to each component of the CAPE framework, resulting in an increase in the number of indicators focused on capacity and decreasing the number focused on experience (7 new indicators, 1 expanded indicator, 13 indicators condensed to 4 indicators by combining with like indicators, 5 removed indicators; Table 3). For example, we added the indicator *"Teachers and other educators are receiving*

ongoing professional learning and support to teach computer science/computational thinking and/or integrate computational thinking into their disciplinary classes" to the Capacity section of the CT Engagement Inventory. To better represent the range of places districts might be in developing their inclusive pathway, we changed the method of marking an indicator present or not from a binary "yes" or "no" to a multi-level drop down with the options of "not present", "developing", "highly developed", and "cannot answer - data not available". Finally, we added a cover page to the CT Engagement Inventory with instructions for use and a brief explanation of the CAPE framework with additional resources to support district leaders who are using the CT Engagement Inventory to better understand the components of CAPE. Version B of the CT Engagement Inventory can be accessed at: [url removed for review].

Table 3. Updated indicators on Version B of the CT Engagement Inventory

Capacity	
New	Our district has designed and implemented a CT Pathway that is consistent across classrooms, cumulative from year to year, and competency-based.
Expanded	Students can fulfill graduation requirements and/or receive dual credit with computing courses.
New	Families, community members, and local businesses are aware of and support the district's computing initiative.
New	District-level and building-level administrators are aware of and support our district's computing initiative.
New	Teachers and other educators are receiving ongoing professional learning and support to teach computer science/computational thinking and/or integrate computational thinking into their disciplinary classes.
New	District-level administrators, building-level administrators, teachers, and counselors are receiving ongoing professional learning on patterns of marginalization and exclusion experienced by Black or African American, Latinx/Latine, Pacific Islander, or Indigenous students, students with disabilities, and girls or non-binary students and research-based strategies to counter these patterns.
New	Our district has the necessary computer science and/or computational thinking curriculum/lessons, software, hardware, and/or other resources to support our computing initiative.
New	Our district has a means of assessing students' computing knowledge and outcomes.

Participation	
Combination of Version A indicators	Computing courses (computer science or computational thinking integrated) are required for all elementary, middle, and high school students.
Experience	
Combination of Version A indicators	Computing courses (computer science or computational thinking integrated) give students the opportunity to develop and express their interests, experiences, and identities through computer science or computational thinking activities and computing tools and connect those CS/CT learning experiences to students' home, community, and interdisciplinary knowledge.
Combination of Version A indicators	Computing courses (computer science or computational thinking integrated) utilize the best practices for accessible instruction, including principles of collaboration, student voice and choice, and Universal Design for Learning.
Combination of Version A indicators	Computing courses (computer science or computational thinking integrated) teach students about biases in technology, acknowledge and challenge power dynamics associated with race and representation in computing, and challenge stereotypes about who a computer scientist is.

Implications for Researchers and District Leaders

There is a need for greater focus on the development of inclusive computing learning opportunities at the district level. Particularly, the development of research-based tools to support district leaders to design and monitor their computing initiatives by collecting and examining data. Our research team has found significant success designing and implementing such tools in partnership with our district practice-side partners within our RPP (e.g., Authors, 2024).

Prior research has shown that boundary crossing within research and design projects provides opportunities for partners on both sides to learn each other's tools and objectives and, particularly in the case of educational leaders, integrate the tools and practices into their own work. Boundary crossing can lead to educators developing research attitudes with regards to their teaching and researchers incorporating educational improvement within their research objectives (Schenke et al., 2017). Within this project, these activities have supported boundary crossing by research- and practice-side partners and disruptions to traditional research paradigms in ways

that were productive for both research and practice and enabled each partner to bring their own expertise and perspectives to the work (Ackerman & Bakker, 2011; Farrell et al., 2022). Boundary objects have been found to support individuals in boundary crossing by facilitating parts of communication and collaboration across perspectives by anticipating the needs of partners with those perspectives, although they cannot replace communication (Akkerman & Bakker, 2011). Within this work, research- and practice-side partners were able to span the boundaries between research and practice and use the CT Engagement Inventory as a tool to navigate differences and develop new skills and knowledge (Ackerman & Bakker, 2011; Wentworth et al., 2022). The research-side partners, many of whom have a background as educators but are now positioned as researchers within a non-profit, and practice-side partners, some of whom have conducted and participated in education research, but who primarily work within district-based teaching, teacher-support, and administrative roles, were able to better access information from each other and examine the data from a shared viewpoint by having that information presented within the CT Engagement Inventory. The tool made more accessible to the practice-side partners research on practices for inclusive computing learning experiences by synthesizing results from many research articles into concise indicators and empowered the practice-side partners to gather and present data about their district and analyze that data toward their district goals. For research-side partners, the tool was a boundary object that not only moved forward the project as a whole and worked toward improving computing learning opportunities within the district, but could be used to support research production (Wentworth et al., 2022). In doing so, the CT Engagement Inventory, as a boundary object, can support not only the districts who participated in the co-design, but also the districts who later engaged with those tools collaboratively to develop new knowledge and routines (Schenke et al., 2017). Given that

completing the CT Engagement Inventory is a yearly routine, district leaders are able to engage with the tool and will be able to engage in data gathering and analysis cyclically, utilizing the tools developed through their boundary crossing. Our project has used additional tools as boundary objects to further support building these skills, boundary crossing, and collaborative sensemaking of data between research- and practice-side partners (Authors, 2024).

While all of our district partners previously knew what an inclusive computing pathway is and the imperative for broadening participation in computing, the CT Engagement Inventory expanded their inclusive pathway goals towards building a more inclusive computing ecosystem potentially because it expanded awareness of different components of inclusive computing, created common language across partners, and offered opportunities for structured reflection. We encourage researchers to not only consider research- and data-focused tools, but also to consider how their development and collaborative use can enable this cross-team learning. Continuing work within our project explores collaborative meaning making of data with districts utilizing boundary objects and how collaborative data analysis can lead to not only inclusive pathway goals, but also action plans for enacting those goals.

At the district level, the results of the CT Engagement Inventory highlighted the importance of expertise across the district hierarchy and the significant role that both curriculum and professional learning play in having inclusive computing learning opportunities for all students. To date, significant work aimed at creating more inclusive CS and CT learning opportunities has focused on the development of both curriculum and professional learning opportunities for educators (e.g., Coenraad et al., 2020; Franklin et al., 2020; Goode & Margolis, 2011). While these curricula and professional learning opportunities are available, their use is still not widespread and the political environments of some states could limit opportunities to

adopt computing curricula specifically focused on culturally relevant learning or equity. Therefore, it could be helpful to pair the CT Engagement Inventory with other tools specifically designed to support teachers to attend to equity and inclusion within their curriculum (e.g., the TEC Rubric (Weintrop et al., 2019)) and support using such tools to determine opportunities to add to curricula in ways that will support inclusion of all learners, particularly historically and systematically excluded learners.

Limitations

While the districts that participated in this research and utilized the CT Engagement Inventory represent a variety of urbanities, sizes, locations, and student populations, this study was limited to six districts who have been working closely with researchers for three or more years and who have been developing CT pathways for at least as long. Their significant knowledge of both the need for inclusive computing learning opportunities and inclusive pedagogical strategies could impact their use of and response to the CT Engagement Inventory. Newer districts to computing initiatives could have different experiences completing the inventory, as our district leaders pointed out in their feedback. Additionally, given that the districts and researchers work closely in an RPP and worked on their inventory over a multi-month time period, it is possible that the change in focus of the district goals could have been impacted by other work the groups are doing together. While we think this is unlikely given the relative temporal proximity of finishing the CT Engagement Inventory and writing their goals, knowledge of what was discussed in one-on-one meetings, and district responses to how the inventory led to their inclusive pathway goals, the impact of learnings and experiences outside of the inventory is possible. Finally, this group of districts might not be representative of all districts due to being mostly small to medium sized suburban districts. We plan to further

explore the use of the CT Engagement Inventory with additional districts to explore how experiences are similar and different across contexts.

Conclusions

As the CS for All community continues to work toward broadening participation within computing learning opportunities at the K-12 level, work on all levels of education (classroom, school, district, and policy) are necessary to ensure that all students, particularly historically and systemically excluded learners, receive access to high-quality computing learning opportunities. The past decade has witnessed significant gains in K-12 computing education for students. Yet many students still experience marginalization in and exclusion from computing courses. Supporting districts to set goals for more inclusive computing learning experiences is essential to ensure inclusive computing learning opportunities reach marginalized students, this paper demonstrates a tool to support districts in leading the way. By working at the district level, we aim to support our district partners to develop inclusive CT pathways that provide high-quality, student-relevant computing opportunities. District leaders need tools to perform this work and center inclusive student engagement. The CT Engagement Inventory works toward these goals and provides a scaffold for district leaders to examine what currently exists and set clear, productive goals for developing their inclusive CT pathway. Even after decades of work, the CS education community is far from reaching its goal of full participation in computing. We must partner with districts and educators to develop and implement tools to further this goal and ensure all students have the opportunity to engage in computing.

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