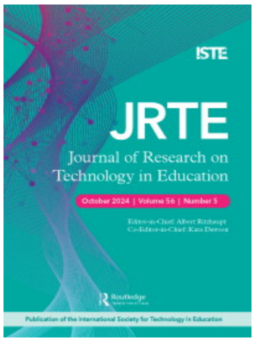

Journal of Research on Technology in Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ujrt20

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To cite this article: Emi Iwatani, Merijke Coenraad & Kyle M. Dunbar (10 Sep 2024): Bridging cultures and computing: Exploring the relationship between Appalachian problem solving and computational thinking, Journal of Research on Technology in Education, DOI: 10.1080/15391523.2024.2399257

To link to this article: https://doi.org/10.1080/15391523.2024.2399257

Published online: 10 Sep 2024.

JOURNAL OF RESEARCH ON TECHNOLOGY IN EDUCATION
https://doi.org/10.1080/15391523.2024.2399257

Bridging cultures and computing: Exploring the relationship between Appalachian problem solving and computational thinking

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ABSTRACT

Students in Appalachia have a heritage of problem-solving. We explore how computational thinking (CT) relates to and complements this heritage by analyzing 34 local ingenuity stories, and perspectives from 35 community members about the relevance of CT. We found the two problem-solving approaches are meaningfully different, but can be used in concert. Since equating them could contribute to confusion and cultural erasure, researchers and educators bringing CT as a problem solving strategy into rural and other resourceful cultures must clarify what they mean by "CT helps problem solving." In these cultures, CT skills are better introduced as new tools to expand students' problem-solving toolkits, rather than tools that are identical to or better than those traditionally used in their culture.

ARTICLE HISTORY

Received 31 March 2024
Revised 24 August 2024
Accepted 28 August 2024

KEYWORDS

Computational thinking; problem solving; Appalachia; rural; cultural responsiveness; complex problem solving; CS education

Introduction

Teaching computational thinking (CT) within K-12 schools has become increasingly common as a strategy for students to learn problem solving and better understand the computational world around them. Initiatives and standards at the district, state, and national level aim to ensure that students have access to CT and computer science (CS) learning opportunities (Code.org et al., 2022; Coenraad et al., 2021b; K-12 computer science framework, 2016). Yet availability of coursework is not enough. Given the stereotypes and societal beliefs around who belongs in CS (Google, 2015), initiatives are needed that demonstrate alignments between CT/CS and students' cultures and interests in inclusive and equitable ways (Kapor Center, 2021) and directly counter the image of a programmer as an isolated man (Brauner et al., 2018). Students from non-dominant cultures need opportunities to see themselves and people who are like them as computer scientists and have their voice valued within CS and CT learning opportunities (Kapor Center, 2021; Mills et al., 2021; Ryoo, 2019). Previous efforts in culturally responsive computing education have highlighted the importance of connecting instruction with local communities and culture (Morales-Chicas et al., 2019). However, we know less about how to develop activities that go beyond using culture as a context in which to teach computing, and how to align CT with cultural heritage in a way that honors the significance of each, particularly within rural communities and within formal classroom learning environments.

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Background

Our project's core concern about how CT and Appalachian problem solving relate

This research originates from a research practice partnership (RPP) in Eastern Kentucky, part of Central Appalachia, where two districts sought to provide computing learning opportunities that connect to "Appalachian problem solving" (also referred to as "Appalachian ingenuity"). In supporting middle school teachers to design problem-based learning units on these topics, we encountered a fundamental challenge in describing the relationship between CT and Appalachian problem solving, which seemed conceptually related yet distinct.

Computing education scholars have conceptualized CT as a set of practices and/or skills that are relevant to computing professionals, but can be useful to a broader range of activities and purposes (Barr & Stephenson, 2011; Weintrop et al., 2016; Wing, 2006). As such, many definitions and strategies for utilizing CT within K-12 education focus on its integration within disciplinary subjects (Lee & Malyn-Smith, 2020; Mills et al., 2021; NGSS Lead States, 2013). While many characterizations of CT exist, our project defines CT in alignment with the Kentucky Academic Standards for Technology (Kentucky Department of Education, 2020), which characterizes learning goals for "computational thinker" primarily as *data practices* and *automation* through technology, with an emphasis on understanding and designing algorithms.

Appalachian problem solving refers to ways that Appalachians have tended to solve problems and innovate solutions, historically and today. Many anecdotal examples exist, including making farm implements and other necessities with available materials, and creating sophisticated technologies for use in coal mines (Iwatani et al., 2022). Appalchian problem solving is a guiding concept within our CSforALL initiative, where the project goal is to create, implement, study and refine project-based CT lessons that are connected to Appalachia's cultural heritage of problem solving. Our hope was for teachers to design these lessons, so students will experience CT in ways that they may find consonant with their cultural values and useful toward their goals and aspirations.

In describing this curriculum design project to teachers, it was initially tempting for many of us leading the project—researchers and practitioners—to present CT and Appalachian problem solving as equivalent or similar. This was in part because both relate to problem solving and it sounds affirming to say, "CT is just a new term for Appalachian problem solving." However, we recognized that this is problematic as it might present distorted views of Appalachian problem solving and CT, and potentially lead to cultural erasure, if the two conceptions are sufficiently different (e.g. if students learn CT believing they are learning Appalachian problem solving and it turns out they are not). For a while therefore, we defined these notions separately without specifying their connections or differences. When conducting professional development for teachers, we referred to CT as *problem solving using skills and practices underlying modern computing*, and described Appalachian problem solving as *traditional approaches to challenges*. However, this approach of staying silent about the relationship between CT and Appalachian problem solving also felt inadequate because it provides no rationale to teach these skills together, fails to connect content to culture, and still risks that teachers/students will incorrectly or unhelpfully equate the two skills, even if we do not explicitly present them as equivalent.

The biggest concern we (authors) had was about unintentionally eroding Appalachian culture by over-privileging highly analytic epistemologies and values that are characteristic of the cultures of "Western, educated, industrialized, rich and democratic" people (or "WEIRD" people, per Henrich, 2020) from which modern computing was most likely born (O'Regan, 2021). We knew from both scholarship and personal interactions with Eastern KY colleagues that *familism* or *kinship* tends to be foundational to Appalachian core and sub-cultures (Beaver, 1986; Hicks, 1976; Jones, 1994; Keefe, 2005; SOAR, 2018). As Henrich (2020) summarizes, psychologists have found that "[societies with] intensive kinship cultivates more holistic thinkers who focus on broader contexts and on the relationships among things, including interconnections among individuals, animals, or objects" whereas societies with "less intensive kinship" tend to "foster more analytically-oriented thinkers who tend to parse the world by assigning properties, attributes, or personalities to people and object, often by classifying them into discrete categories according to presumed underlying essences or dispositions" (pp. 221-222). Given that the core competencies of computing are so squarely about objectification and analytical thinking, we worried that promoting CT (rooted in computing, and therefore in cultural priorities of "WEIRD" people) would inadvertently contribute to erosion of relational and holistic thinking that may be a natural and valuable asset of people in Eastern KY.

In this way, our project faced a very practical need to identify similarities and differences between CT and Appalachian problem solving, and to do so in ways that local educators and students might intuitively appreciate and find useful. To help us with our thinking, we looked to theories in culturally responsive/sustaining CT education and problem solving.

The relevance of culture in computational thinking education

Within the field of CS education, the importance of considering culture in student learning experiences is well-recognized, especially toward the aim of CS for All (e.g. Kapor Center, 2021; Mills et al., 2021; Ryoo, 2019). Reviews of culturally relevant and sustaining learning opportunities in computing have found that these initiatives can provide value to students through: promoting sociopolitical consciousness raising and student identity development; situating activities within the sociopolitical contexts of computing and society at large; connecting to students' heritage and vernacular cultures; integrating students' lived experiences through connection to their everyday life and self-identity; making connections to students' communities; allowing opportunities for personalization; and positioning students as change agents and innovators with unique and important experiences and knowledge (Madkins et al., 2020; Morales-Chicas et al., 2019; Ryoo, 2019).

For example, the *Scratch Encore* curriculum (Coenraad et al., 2021a; Franklin et al., 2020) integrates student ideas and interests, gathered through participatory design sessions, into intermediate CS lessons, utilizing scaffolding to provide students with opportunities for choice and self-expression in their final projects. *Exploring Computer Science* (Goode et al., 2012; Goode & Margolis, 2011) promotes cultural relevance through an inquiry-based curriculum that is designed to engage students, in part through inviting students to bring their funds of knowledge into the classroom. Their teacher support model places emphasis on inclusive pedagogy. *Digital Youth Divas* (Erete et al., 2021; Pinkard et al., 2017; 2020) engages girls from non-dominant communities in CT through out-of-school time computational making activities that are narrative-based and linked to their interests and home networks. It provides students with opportunities to share their identities, discuss injustices in their community and within computing, share counter narratives, and to envision desired futures in community with one another. As a final example, *Black Girls STEAMing through Dance* (Allen-Handy et al., 2020) is an after-school dance program that leverages the cultural wealth of Black girls through an integration of dance with design, making and coding, through computing learning activities related to dance (e.g. e-textile dance costumes with wearable technologies) and highlighting ongoing connections between coding and dance (e.g. loops, sequences) in a collaborative environment.

Complex problem solving and domain-specific problem solving

Problem solving is a highly important life skill, and has been investigated in different academic domains, from different angles, including psychology, cognitive science, neurosciences, and education (e.g. Barbey & Barsalou, 2009; Davidson & Sternberg, 2003; Gijbels et al., 2005; Hough & Clair, 1995; Nezu & Nezu, 2018). A review by Molnár et al. (2013) distinguishes two classes of problem-solving models that seem useful in better understanding the natures of computational thinking and Appalachian problem solving. The first is *domain-specific problem solving*, which is used to solve many problems specific to single academic domains, and rely on domain specific knowledge and strategies (e.g. mathematical reasoning, historical thinking). The second is *complex problem solving*, used to solve problems that rely greatly on domain general processes to address issues that are "novel, unknown, dynamically changing over time, ill-structured, knowledge intensive, and non-transparent" (Molnár et al., 2013, p.37, summarizing Buchner, 1995; Dörner, 1986). Complex problems can be personal (e.g. finding a life partner that makes you happy) as well as large and global (e.g. climate change, threat of war).

A recent definition by Dörner and Funke (2017) highlights key features of complex problem solving that distinguish it from domain-specific (and potentially other kinds of) problem solving. The first distinctive feature is in its *purpose*. Complex problem solving aims to address ill-defined goals that arise in "dynamic environments" that cannot be solved from relying on problem solving routines and processes from a singular domain. Second, complex problem solving is distinctive in its *outcome*. Because goals are complex and constantly changing, the solutions *"are often more bricolage than perfect or optimal."* Third, it is distinctive in *process*: complex problem solving "combines cognitive, emotional, and motivational aspects" and "usually involve knowledge-rich requirements and collaboration." Furthermore, it needs "creative combinations of knowledge and a broad set of strategies." Routine actions are insufficient for arriving at the outcome.

K-8 computational thinking, as articulated in the KY academic standards, is "domain specific problem solving"

In the state of Kentucky, standards for CT are included in the Kentucky Academic Standards for Technology (Kentucky Department of Education, 2020) and are examples of domain-specific problem solving. One of the stated priorities of these standards is for students to solve problems that can be defined to be suitably explored and solved by "technology-assisted methods such as data analysis, abstract models and algorithmic thinking" (Concept Development—Learning Priority A). By specifying that the *purpose* of this type of problem solving needs to include "technology-assisted methods," these standards are firmly situated in the domain of computing.

These standards further stipulate the use of strategies and methods specific to the field of computing such as decomposition ("Break problems into parts, extract key information") and algorithmic thinking ("Use algorithm design to develop step-by-step instructions for solving a problem"). Thus, the *process* of problem solving also involves domain-specific strategies. These standards do not suggest creatively combining knowledge and strategies from other fields or employing emotional or motivational aspects of problem solving as would be necessary with complex problem solving. And while decomposition is stated as a domain-general learning priority (e.g. "Deconstruct components to understand systems and facilitate problem-solving"), the associated standard specifies use of "technology-assisted methods" and appears to refer to the type of decomposition needed for computing (vs. general problem solving). Furthermore, the standards as a set do not address major aspects of complex problem solving, so even if one CT standard is formulated in a domain-general way, it is difficult to argue that CT (as described in these standards) is domain general.

Furthermore, the framing of these standards assumes that optimal solutions to the problems presented are possible. The ability to arrive at an optimal solution as an *outcome* is another key characteristic of domain-specific problem solving. For instance, the Kentucky standards also state that students should "create and test automated solutions" suggesting that using a systematic process to test solutions will result in an optimal solution. In comparison, complex problem solving may not have an optimal outcome due to the constantly changing nature of their premises and goals.

There certainly can be variation in the extent to which problems are simple or complex within the realm of computing, e.g. how to engineer a computing system for an autonomous vehicle is much more complex than how to develop lines of Scratch code to make an avatar move. However these problems are still within the realm of computing, and it is these kinds of domain-specific problem solving that CT standards are designed to promote.

Possible relationships between CT and how Appalachians have been solving problems

The relationship of CT and Appalachian problem solving is important to consider because it has implications for why and how to teach these approaches to students. Given the conceptualizations of problem solving mentioned above, there are two main possibilities of how these approaches can relate, each with differing implications to culturally responsive/sustaining CT education. The first possibility is that Appalachian problem solving largely overlaps with CT in its mechanics, and just has a different name and different history. If this is the case, a possibly useful, culturally responsive/sustaining way forward for Eastern Kentucky is to teach both conceptions together, and have students become fluent in translating between the two conceptions and understand nuances in the overlaps and differences.

The second possibility is that Appalachian problem solving is quite different from CT, for example, that Appalachian problem solving refers to problem solving in a different domain, or is more similar to complex problem solving. If this is the case, it would seem more appropriate to teach CT separately from Appalachian problem solving, so as not to promote a false sense of equivalence. It would also be important to understand whether and how Appalachian problem solving may be important to teach to Eastern Kentucky students, so that CT education can be complementary or at least not get in the way of the teaching of Appalachian problem solving (if the latter is considered to be important by educators).

Theoretical framework

Throughout this paper, we refer to "culturally responsive/sustaining" computing pedagogy aligned with the literature reviewed above and the current vernacular of computing education research. More technically speaking, our project, including this inquiry, is founded on the notion of *cultural responsiveness* as developed and promoted by Stafford Hood and colleagues articulated through their culturally responsive evaluation (CRE) framework (Hood et al., 2015). CRE recognizes that culture, or "a cumulative body of learned and shared behavior, values, customs and beliefs common to a particular group or society" (Frierson et al., 2002, p. 63) is core to communities' existence, and therefore must be centrally considered in social science inquiry. CRE further stipulates that we must center the voices of the communities that we support, be critical of dominant ideologies including what we ourselves bring in, and work in partnership with marginalized communities to generate inquiry outcomes that support their sustainability and thriving. It is in seeking to be in alignment with CRE's critical, partnership-based, reflexive and practice-transforming approach that we inquire how computing education can value and contribute to the culture, aspirations and ways of being in Appalachia.

An important element of how this framework operates is that we center the perspectives and needs of our Appalachian partners, and de-center the needs of computing education researchers. Since our project started in 2019, the research-side has tried to listen first and widely, and discuss with our partners before applying academic sub-frameworks. Sub-frameworks that have become core to our meaning-making are complex problem solving, Kentucky Academic Standards, community cultural wealth (Yosso, 2005), and civic imagination (Jenkins et al., 2020; Peters-Lazaro & Shresthova, 2020).

Research questions and methods

To help assess between the two possibilities and move forward with our project responsively to culture, we wanted to know more precisely what Appalachian problem solving is, what about it might be useful to teach students, and how that is similar to and different from CT. We also wanted to identify ways to depict the relationship between the two notions in ways that practitioners in Eastern Kentucky find resonant and useful for determining how they may want to teach CT (and if important, Appalachian problem solving) to students. We took a grounded theory approach (Glaser & Strauss, 1967) in our study, drawing largely from 34 Appalachian ingenuity stories, project team reflections over three years on the significance of these stories, and artifacts indicating why local leaders (21 educators and 14 broader community members) believed that computing education is important for the region.

Twenty-one of the ingenuity stories, which we refer to as *educator heritage stories*, came from an exercise in an all-day educator workshop on civic imagination (Jenkins et al., 2020) and CT education. The protocol was for each participant to bring a "memory object" that represented ingenuity in their heritage and to share a story around it, following the Origin Stories activity described in Peters-Lazaro and Shresthova (2020).

Remaining stories, which we refer to as *community stories,* came largely from "inspire talks" for teachers by community members we invited because they were involved or familiar with local innovations that connect well with K-8 CT education. For these, the project team asked the speaker to share stories about their work especially as it relates to CT or computing education, and why it is important for K-8 teachers to teach CT (often described to the speaker as: "coding and related skills" and "collecting and analyzing data") to their students. We also analyzed two community stories that were not inspire talks, but ones that our project had most often referenced as illustrative examples of Appalachian ingenuity (e.g. Iwatani et al., 2022). Artifacts on the value of computing education for the region included approximately 10 hours of transcripts of discussions on this topic including but not limited to inspire talks, as well as districts' CS for ALL vision statements, and public presentations given by district leaders about the project. We also sought support from two experts in Appalachian heritage and culture for RQ3 (below).

The project took place in two school communities in Eastern Kentucky, which is designated as "remote-fringe" by the NCES locale framework, where the median community income is approximately $37,000 according to the 2018-22 American Community Survey, which is about half the national and 60% of the state's median income. One district is located in a small town (population <7,000; district enrollment about 1,000), housing a university and hospital, has high standardized test scores and attracts children of professionals from outside of their county. It has one elementary school and one middle/high school with 39% of the students receiving free/reduced price lunch (FRL). The other district has eight elementary/middle schools and four high schools (population about 37,000, district enrollment about 6,000) with 79% of students receiving FRL. The vast majority of the district's community and student population is white (92+%), and are from English-only households (98%+). The percentage of parents with bachelor's degrees or higher is 15% and 42%, for the larger and smaller district, respectively. District administrators estimate that most students' and teachers' families have been directly impacted by the collapse of the coal industry.

The vast majority of the civic imagination workshop participants were K-8 teachers (17/21), female (16/21), worked in the larger of the two districts (16/21), and referred to themselves as being from Eastern Kentucky and/or having family members from Eastern Kentucky (19/21). Participant evaluations of the workshop and inspire talks were on-the-whole extremely positive, and suggested appreciation and resonance with the topics of Appalachian ingenuity and problem-solving. Majority of the community stories were told by males and/or centrally featured males (four of the eleven community stories were told by females, and two centrally featured females).

Our first research question was: *RQ1. What are characteristics of Appalachian problem solving that Eastern Kentucky might hope to center and preserve in K-8 education (and not accidentally lose or conflate with something from outside of Appalachia)?* We examined ingenuity story transcripts for strong themes and sub-themes that cut across noteworthy stories of local problem solving, checking with Eastern Kentucky project leads about the resonance and plausibility of each theme. Initial codes for Appalachian ingenuity characteristics came from inductive brainstorms with educators, and references on Appalachian culture (e.g. Blessing, 2007; Keefe, 2005; SOAR, 2018). At the same time, we examined artifacts to identify the key learning outcomes that various Eastern Kentucky leaders desired or recommended for the CT pathway project. The intersection between the two—strong themes in local problem solving and local aspirations for K-8 CT education—was what we identified as viable solutions to this research question.

We then examined *RQ2. Is Appalachian problem solving equivalent, or nearly equivalent to CT?* For this, we examined all stories for the presence of the two CT practices that are centered in the state standards: data practices and algorithms/automation. We coded each story for whether each CT practice was (i) explicitly mentioned, (ii) not explicitly mentioned but *likely* to have played a role as part of the problem solving process as told in the ingenuity story, and (iii) not explicitly mentioned and *unlikely* to have played a role in the problem solving process as told in the ingenuity story. We also coded whether each CT practice was a main feature of the innovation story. Three project leads (including two research-side partners and one practice-side partner) calibrated on the coding of three stories where 100% agreement was quickly reached. Subsequently, the two researchers independently coded all remaining stories. The initial agreement was high (79-94%, all differences were off by one level and felt like edge cases) and all disagreements were resolved by discussion between the two researchers.

Because we did not find strong connections to CT in the ingenuity stories in RQ2, especially in the teacher heritage stories, we expanded our search to pursue: *RQ3. What, if any, are illustrative overlaps between traditional Appalachian heritage/culture and CT, prior to the introduction of modern computers?* To answer this question, we engaged in collaborative conversations with two experts in Appalachian heritage and history, to try to identify specific examples in Appalachian culture related to automation, algorithms and/or data practices. After drafting our findings, we shared it with one of our expert partners for feedback, corrections, and additions.

Findings

RQ1. Characteristics of Appalachian problem solving that people in Eastern KY may want to center and preserve in K-8 education

Ingenuity stories shared by teachers and wider community members strongly suggested that *resourcefulness*, which we define as "the ability to use what one has, or make use of the resources that are available," is a central feature of Appalachian problem solving. Resourcefulness characterized the vast majority (31 out of 34) of stories we had examined, and accorded with the project team's general impression that ingenuity stories were often about using what's available to solve problems that came about.

Table 1 summarizes the purposes toward which resourcefulness was applied in the stories: survival and necessity, entertainment, community building and caring, and/or creating tools and infrastructure that are better suited to local conditions. The contemporary stories also included a theme of applying resourcefulness to stay connected to place, such as workforce development, uplifting positive stories and accomplishments, and addressing environmental concerns.

Table 1. Greater purposes for resourcefulness in Appalachian ingenuity stories.

Resourcefulness is often for the sake of…	Examples
Survival and necessity	Quilting to keep warm and/or for income; Canning to preserve food for survival; Creating a feast from humble ingredients
Entertainment	Family tinkering and making to support race car driving; Manually "photoshopping" a group of friends into fashionable clothes from a Sears catalog; Creating music
Community building and caring	Collaborating with neighbors to create a smoker for community cook-outs; Bespoke gifts to friends and family made from available materials; Awards event to celebrate Appalachia; Recent entrepreneurial efforts to bring jobs to Appalachia
Creating infrastructure or tools to be more useful in harsh/mountainous conditions	Creating a lawnmower suited for mountainous landscapes; Pikeville cut-through project that rerouted the river to prevent flooding

The stories and discussions with Eastern Kentucky educators surfaced four approaches or methods through which resourcefulness tends to be enacted. One characteristic, related to a problem-solving orientation, is how people *tend to jump into action without much hesitation, try things out, and not be afraid to change if things do not work the first time*. This characteristic was pointed out by a teacher who came from the rural south, who shared that from his "outside perspective" that people in Appalachia seemed very action-oriented and less self-conscious about starting new things. As an example, he shared how his student one day said that she might want to make candles for fun, and the next day she had already done it. "[T]here's no delay in my students. It was an idea she had, and then she just did it. There was no thinking about it." He also mentioned how one neighbor "popped up" to fix another neighbor's carburetor. "It would take me a week or two of thinking about trying to figure out how we put that together. They just did it." Reflecting on this privately later, two Eastern KY educators discussed how true it was that people in Appalachia tend to be this way. One shared with the other: "I used to think that was a bad thing that we jump into trying to solve things without thinking about it too much, but now I see that it can be a strength."

Another commonly mentioned approach to resourcefulness was *repurposing and connecting a variety of available objects in ways that are useful to the task*. This was evident in many stories from creating lampshades out of coffee cans, lawnmowers out of drone parts, and quilts out of feedsack. *Networks of friends and family* was another type of resource that many of the ingenuity stories featured for accomplish projects and solve problems. Finally, resourcefulness also applied to *self-reliance, including drawing upon one's effort, grit and experience-based knowledge*.

Perspectives from 35 education and workforce leaders suggested that not only is resourcefulness typical of traditional Appalachian problem solving, it is likely a characteristic that people in Eastern Kentucky would want to highlight and try to preserve through their K-8 CT education. When asked about the primary desired outcome of K-8 CT education, the vast majority of these leaders explicitly and consistently emphasized complex problem solving, for which resourcefulness would be highly beneficial. Table 2 describes the types of learning outcomes that community leaders desired or recommend for Eastern Kentucky students through the CT pathway project. Many leaders wanted students to become able to solve problems so they can contribute meaningfully to the complex issue of local workforce revitalization, whether it be succeeding in "jobs that don't exist yet" (district leaders), "expand our workforce" (District 1 SCRIPT team, described in Table 2 note), or to creating new jobs in Eastern Kentucky (Workforce leader 2). In conjunction with these outcomes, leaders mentioned the importance of skills and characteristics such as creativity, entrepreneurism, collaboration, working across sectors, perseverance, self-motivation, work ethic, and passion. Many of these predicate upon or overlap with resourcefulness that we observed in the stories.

As a related aside, in discussions about the importance of creating CT pathways, there were relatively few mentions about the importance of domain-specific CT skills. These were mentioned by engineers at a software development company when they were asked what might be important for students to know if they wanted to work at their company. Notably, we did not hear from any education or workforce development leader a perspective that we sometimes hear in Silicon Valley: that students should learn programming to be able to get internships and high-paying jobs in leading technology companies.

RQ2. Whether Appalachian problem solving is equivalent, or nearly equivalent to CT

Tables 3 and 4 summarize the number of ingenuity stories where CT practices were explicitly mentioned as playing a role in problem solving, not explicitly mentioned but likely played a role, and not explicitly mentioned and likely did not play a role. Table 5 provides examples of how CT practices played a role (or not) in the stories. We found that algorithms/automation either played or likely played a role in 84% of the community stories, but likely played a role

Table 2. Types of learning outcomes that community leaders desire or recommend for Eastern Kentucky students through the CT pathway project.

Community leader	Learning outcome(s) desired or recommended through K-8 CT pathway project	Problem solving emphasis (if any)
District 1 SCRIPT team*	"Our CS for All vision: We believe in CS because All students have the opportunity to be competitive in today's global economy, demonstrate leadership and success, inspire innovative solutions, and grow and expand our region's workforce."	Complex and domain specific (CS/CT and other)
District 2 SCRIPT team*	"Our CS for All vision: We believe in CS because ALL students should possess competencies and skills to become citizens who recognize problems and create innovative solutions."	Complex
District leaders	"Build a CS/CT Pathway K-8: We are preparing our students for jobs that don't exist yet. We must be preparing them to creatively problem solve in groups and develop perseverance in their work." (2022 KySTE presentation; Emphasis in the original) [link]	Complex
Teachers discussing how they might prepare students for 30 years into the future	"So the biggest thing that we talked about, [that we can do] in the classroom, is letting kids solve problems. I mean real problems. Problems that they see. Landslides. That's a problem in this area. …I think if we can be more invested in solving problems that's relevant to them, I think it would hopefully open up that creativity with them." Teachers also discussed the importance of spending time with kids (mentoring etc), to support them to acquire "life skills that are necessary in order to just survive in the real world," and "not only to just push themselves to be motivated, but to be better people altogether."	Complex
Workforce leader 1	Urges K-8 teachers to help foster pride in students about who they are and where they are from (asset-based narrative development), which may be accomplished by "creatively to get kids focused in problem solving," and to learn required content and skills alongside it. He also mentioned the importance of supporting entrepreneurial approaches to problem solving, and of working within and across stakeholder sectors (e.g. education and workforce).	Complex
Workforce leader 2	Want teachers to foster students who can create new jobs, rather than preparing them in the specific skills of today or tomorrow.	Complex
Workforce leader 3	Want students to think critically and solve problems that they encounter, which importantly ties to education in computational thinking.	Complex
Workforce leader 4	Important for future employees to have, computational thinking skills, digital literacy and an entrepreneurial mindset, in addition to soft skills such as work ethic and passion. Projects in innovation-driven enterprises can involve a range of technical and creative skills (e.g. UX, UI, design, film production, marketing, communications, acting). Extremely important to be able to build and maintain relationships, to land projects and make them a success.	Complex and domain specific (CS/CT and other)
Ag-tech company	Important for future employees to have "soft-skills," such as work ethic and passion.	Unclear from presentation
Telecommunications company	Postsecondary degrees (e.g. in engineering) have not been important for hiring so far, as the company has benefited from capable and resourceful employees without formal training for even the technical work. However, this may change in the future.	Unclear from presentation
Software development startup employees	"[What I wished they taught me in school is] CS, CS, CS, and especially the knowledge of what an economically viable career option it could be" (Engineer 1). The "ability to think logically" (Manager) is considered helpful overall. "Looking at data structures and algorithms," is something "language agnostic" that would benefit students interested in software (Engineer 2).	Largely domain specific (CT and CS)
Musician	Hope that teachers will encourage interested students to create their own music to express how they feel, and to let them know that this is possible and easy to do at home through digital technology.	Largely domain specific (digital music)

*District SCRIPT teams consisted of five teachers and administrators that have used the Strategic CSforALL Resource & Implementation Planning Tool (https://www.csforall.org/projects_and_programs/script/) with the help of a trained facilitator to collaboratively envision, self-assess and set goals to create a computing education implementation plan for their students.

in just 38% of educator heritage stories (with none explicitly mentioning the practice) (Table 4). The four stories that explicitly mentioned algorithms/automation did so in diverse contexts of digital music, ag-tech, app development and event management, where task-automation and/or coordinated consistency across people or occasion was required as a critical part of problem

Table 3. Number of times that automation/algorithms played a role in community and teacher heritage stories.

Automation/algorithms	Community stories ($n = 13$)	Teacher heritage stories ($n = 21$)
Explicitly mentioned	4	0
Not mentioned but likely played some role	7	8
Not mentioned and likely did not play a role	2	13

Table 4. Number of times that data practices played a role in community and teacher heritage stories.

Data Practices	Community stories ($n = 13$)	Teacher heritage stories ($n = 21$)
Explicitly mentioned	4	0
Not mentioned but likely played some role	4	2
Not mentioned and likely did not play a role	5	19

Table 5. How CT practices played a role (or not) in the Appalachian ingenuity stories.

Automation/Algorithms: Designing a process (algorithm) to make things more consistent across people or occasion; AND/OR automating something so less human effort needed

- CT practice was <u>explicitly mentioned</u> as part of the ingenuity story (4 community stories, 0 educator heritage stories)
  - Digitalization of music allows people to listen to and create music any time, anywhere, even without instruments or people. It has allowed some musicians to work with Grammy winning artists from Appalachia.
  - Many things are automated in the local hydroponic plant, allowing for consistent high-quality crops to be produced regardless of weather.
  - Automation/algorithmic thinking is required to create an app to reduce bullying.
  - Many people need to work toward a goal to make an annual awards event happen without micromanaging; voting and registration are automated through digital platforms; Also they likely have an algorithm/recipe to make the annual event.
- **CT practice was <u>not explicitly mentioned but likely played a role</u> as part of the ingenuity story** (7 community stories, 8 educator heritage stories)
  - E.g., Creating lawnmowers and mower parts likely required automation.
  - E.g., Quilting and watching children every day requires repeated processes, and therefore likely involves some kind of algorithmic thinking.
- **CT practice was not explicitly mentioned and <u>likely did not play a role</u> in the ingenuity** (2 community stories, 13 educator heritage stories)
  - E.g., Coming up with an idea for a company that may draw on local assets and support regional workforce development.
  - E.g., Hand-crafting specific pieces of artwork, farm implements, and furniture out of available materials for various purposes.**Data practices**: Collecting and/or analyzing data to identify useful patterns to describe/understand phenomena or predict the future

CT practice was <u>explicitly mentioned</u> by storyteller (4 community stories, 0 educator heritage stories)

- Local app developer examined data from prototype apps and feedback from local students and adults to improve the app
  - Various data on hydroponic growing, e.g. temperature and soil moisture, is collected and monitored to grow tomatoes in Eastern KY; Trends in data about local precipitation was relevant in deciding E KY location.
  - Information about a local electric plant is collected and monitored for safety; also data about climate was likely consulted to come up with the idea, and many experiments and financial data were likely important to the project.
  - **CT practice was <u>not explicitly mentioned but likely part</u> of the example/story** (4 community stories, 2 educator heritage stories)
- To successfully launch and sustain a local awards event, collection, examination and use of several types of data are likely to be important, including: voting data, attendee data (from registration and surveys), and financial data.
  - To launch and sustain a successful local e-commerce business, it is likely that the owners examined all kinds of data related to e.g. demand, supply, customers, product, and revenue.
  - Might have calculated financial prospects; Video explicitly mentions looking at information from various business sectors to see what might work in Appalachia (but that didn't look quantitative)
  - Likely that they looked at data to figure out where to build their next tower.
  - Likely relied on topographical/geological, climate, financial data, to name a few.
  - **CT practice was not explicitly mentioned and <u>likely did not play a role</u> in the ingenuity** (5 community stories, 19 educator heritage stories)
- E.g., Creating digital music to express a story or emotion; Sharing local stories through documentary film-making; Coming up with an idea for a specific local agri-business (based on conversations rather than data) and implementing it (most processes are manual).
  - E.g., Hand-crafting specific pieces of artwork, farm implements, and furniture out of available materials.

solving. Most heritage stories, and one community story were about the ingenuity and resourcefulness associated with individuals creating singular bespoke products (e.g. an implement, furniture, artwork or an idea for a company), and therefore likely did not involve automation or algorithms. The exception was with heritage activities that involve repeated procedures within the creation process, such as quilting and canning, where consistency and efficiency tends to matter, and therefore algorithmic thinking or process was likely followed although never explicitly mentioned. We discuss this further in the section about RQ3, below.

Data practices played or likely played a role in 62% of the community stories and played a likely role in 10% of the educator heritage stories (Table 5). The three community stories that explicitly mentioned data practices were in the contexts of app development, ag-tech, and monitoring aspects of safety in an eco-friendly power plant. Data practices also likely played roles in contexts of business including e-commerce, event management, and civil and electrical engineering. The two educator heritage stories that related to data practices were about canning, where we thought that community knowledge and personal tracking of exact conditions would be needed to can safely and support any subsistence farming that was involved.

Overall, 93% of the community ingenuity stories involved algorithms/automation or data practices or both, with 54% explicitly mentioning at least one of these practices. On the other hand, just 38% of teacher heritage ingenuity stories involved algorithms/automation, or data practices or both, 0% mentioned these explicitly, and the inferred connections tended to be weak (e.g. we inferred that cooking and quilting contain some algorithmic thinking although the storytellers did not mention it). We also observed that even when the stories involved these CT practices, the practices were just a small part of the solution, and typically not the most important or compelling part. For example, the most compelling part of the local engineer who invented a lawn mower was how he tinkered and strung together parts from existing commercial products, not that he automated part of the production system. The compelling part of quilting and canning stories were about how family members expressed their love through resourceful creativity, rather than about the efficiency, streamlining or optimization they had achieved through the CT practices. These observations thus strongly suggest that while Appalachian problem solving can sometimes involve CT, it is not equivalent to CT. Furthermore, it suggests that learning and practicing heritage problem solving, without further intentionality or scaffolds to teach CT, is unlikely to help students become computational thinkers, at least in the ways that the Kentucky Academic Standards require.

RQ3. Whether there are illustrative overlaps between Appalachian heritage and culture and CT, prior to the introduction of modern computers

The Appalachian culture experts helped to confirm, expand and clarify how algorithms/automation can be found in traditional Appalachian crafts such as quilting, woodworking, and weaving, even when they were never explicitly mentioned in the heritage ingenuity stories. Quilts often follow patterns with one or more types of blocks across the quilt, and quilters follow step by step processes (algorithms that are written, shared orally, or created anew by the quilter) to bring together individual pieces of fabric. This process is repeated for each matching quilt block until enough pieces are produced to reach the desired size; these are then sewn together with or without sashing to form a quilt.

Similarly, woodworkers utilize algorithmic thinking through creating a step-by-step process to generate a solution and reproduce it as needed. As with quilting, most woodworkers use or make patterns to guide the design process and rely heavily on the sharing of knowledge to work through creation and iteration. For example, woodworkers skilled in coopering would utilize simple patterns and tools to create identical staves—the sides of a bucket. Hand-carved buckets are the result of both cultural diffusion and problem solving; while a simpler method for creating a water-bearing vessel might be carving a wooden bowl, this method lacks efficiency and practicality. Instead, woodworkers invested the time and resources into designing processes for making buckets that were water tight while also conserving the precious resources of the Appalachian region.

In weaving, crafters not only utilize algorithms in ways similar to quilters and woodworkers, but some crafters also utilize automation through non-computerized looms. While computerized looms exist, they are typically industrial. But most household looms, including those handmade in the Appalachian region since the arrival of Europeans, provide automation of processes. Loom styles brought over by European settlers feature harnesses—sometimes up to eight, but always at least two. These harnesses are connected to pedals which raise and lower at least one harness at a time, so that one is always up and the other is always down. This creates a shed, a space between the threads for the shuttle to pass. However, most weavers use the threading of the harnesses to create repetitive designs. By planning ahead and consulting written graphs of patterns, weavers can automate the process of their craft and manipulate the threads and colors to make both utilitarian and esthetically pleasing cloth.

In terms of historical examples of data practices (i.e. collecting and/or analyzing data to identify useful patterns to describe/understand phenomena or predict the future), they were difficult to identify within everyday household activities and activities prior to industrialization, but we found potentially illustrative examples in Eastern Kentucky's history of coal mining. Data practices were common in the collection of safety records and testing of coal samples to determine quality and market value. Data about the rock and mine structure was also important for mine safety (e.g. determining where to place roof bolts for stability). To what extent and how exactly this was done prior to the introduction of modern computing is an area we still need to investigate.

Discussion

What model describes the relationship between CT and Appalachian problem solving accurately, and in a culturally affirming way? How is it useful?

Figure 1 depicts the relationship we see between Appalachian problem solving and CT as a result of this inquiry. We conceive of Appalachian problem solving as a subset of complex problem solving related to surviving and thriving within the cultural context of Appalachia. This characterization seems appropriate because Appalachian problem solving pertained to solving

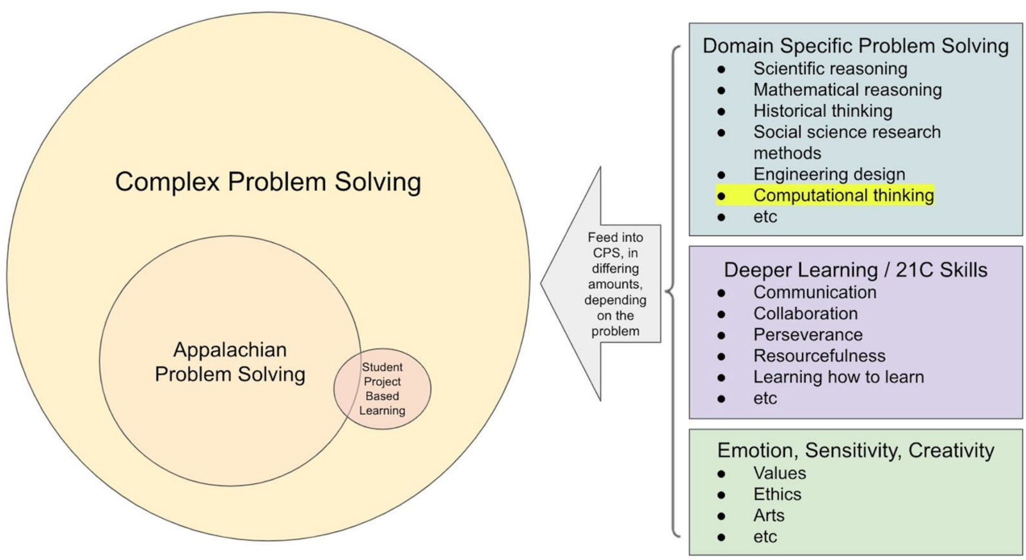

Figure 1. Relationship between Appalachian problem solving and CT.
Note: Complex problem solving, Appalachian problem solving and problem-based learning experiences that Eastern KY educators wish for their students to engage in, partially overlap. The skills and attributes listed on the right hand side are neither comprehensive nor exact, and many of these interrelate and overlap within and across categories.

various types of open-ended issues that have no optimal or single solution, and cannot be solved by repeatedly applying a particular set of solution routines (Table 1, left column, e.g. "survival," "entertainment"). The right hand side of Figure 1 lists examples of factors that complex problem solving (including Appalachian problem solving) might rely on, depending on the nature of the problem. These include and not limited to: domain specific problem solving skills, deeper learning or twenty first century skills, and non-analytical elements of cognition and motivation that are essential to complex problem solving (Dörner & Funke, 2017; Nezu & Nezu, 2018). We see CT as essential for solving problems in the domain of computing, although it alone is insufficient for solving complex problems. We also believe that students can use CT in combination with various other factors, to help solve many (but not all) kinds of complex problems.

This conception is useful in explaining a number of phenomena that used to puzzle us, for example, why a tech-savvy Eastern KY colleague remarked that "we have plenty of Appalachian ingenuity, but the CT stuff feels like a different part of the brain," and why we struggled so much to write survey questions that referred to CT in a culturally accessible way. It also explains why we've resisted suggestions along the lines that CT can "save" rural areas by teaching students problem-solving, and at the same time we've resisted suggestions that CT is what rural areas have been doing and teaching all along.

Importantly, our project can now introduce Appalachian problem solving and CT to teachers and students in relation to one another, without conflating the two, and with due respect to the usefulness of each. In educator trainings, we now share the following framing that might also apply in other ingenuity-rich cultural contexts:

1. Appalachian problem solving encompasses the various ways in which people in the region have solved myriad open-ended problems related to surviving and thriving in the mountains, and is characterized by a high degree of resourcefulness.
2. CT that is centrally featured by the KY standards (algorithmic thinking, automation and data practices) are skills and practices that are central to the field of modern computing. These are important to teach because it can not only help students who want to become programmers, but also expand the types of open-ended, complex problems that all students could solve.
3. Appalachian problem solving and CT are not the same thing. Appalachian problem solving consists of a *large set of skills and understandings related to resourcefully supporting others through making and creating*, while CT is a narrower and more precise set of skills and understandings that can sometimes support students to solve community problems.
4. For many types of problems that Appalachians have resourcefully solved, CT hasn't been a relevant or essential part of the solution. However, this doesn't mean that people in Appalachia never practiced CT until the introduction of modern computers. For example, algorithmic thinking plays a role in traditional Appalachian quilting, weaving and woodworking. Data processes, automation and algorithmic thinking play important roles in various aspects of coal mining.
5. If we want students to learn how to resourcefully solve problems they've never encountered before, teaching CT (as described in the standards) will be powerful and essential but won't be enough. We need to give students experience in *complex problem solving*, which is why we want students to work on *(complex-)problem-based learning* lessons, and have them leverage and draw inspiration from Appalachian problem solving. At the same time, we want to teach students strong CT skills as something to have handy in their problem-solving toolkit.

Implications for CS for all

Given our limited data sources and analytic capabilities (e.g. we have little/no expertise in anthropology and psychology), what we shared about Appalachian problem solving are exploratory and simplistic. Yet our study suggests the importance of considering potential mismatches between CT and culturally familiar and/or preferred ways of thinking and knowing in kinship-intensive and resourceful cultures (e.g. many rural, Indigenous and non-Western communities). It was thought-provoking for us, for example, to realize that historically and even today, many Appalachian businesses probably had no serious need for calculation and graphing of customer trends and preferences if their operation is of a local scale and they know most of their customers personally. If we teach data analytics through a problem-based lesson of e-commerce, would we also be inadvertently sending students a message that the way to learn about customers is by surveys and statistics, rather than through personal interactions? To be able to identify and sit with these kinds of tensions, it seems important to learn from interdisciplinary studies about how ideas and technologies created by Western, educated, industrialized, rich and democratic societies (Henrich, 2020), including those related to computing, have been found useful or not in less metropolitan and more kinship-intensive societies.

Related, our findings strongly support and extend CS for All's recommendation for practitioners and researchers to carefully consider *why* computing education is important (Santo et al., 2019). The process of discovering the "why" for kinship-intensive cultures may require repeated and trusting conversations between computing experts and experts in local culture. Notions such as *complex problem solving*, *resourcefulness, caring for community, facing uncertain futures, self-sufficiency* and *cultural sustainability* might serve as helpful starting-points for those in kinship-intensive and resourceful cultures to consider possible reasons and approaches to leveraging CT. Our RPP's shared reason for CS/CT evolved considerably across five years, as our collective understandings of CT and Appalachian culture deepened. We began with how CS/CT might help academic learning by improving engagement" and "might help local workforce development," to how it "might help students be better problem-solvers." And now we have a more nuanced idea (based largely on this study), that "CS/CT might help students survive better in an uncertain future, by expanding their toolbox of complex problem solving."

Finally, our study suggests that it may be effective to teach CT conjunction with and in relation to complex problem solving, particularly for students who come from communities full of resourceful problem-solvers. How to accomplish this for all students in K-12 (vs. in elective programs) is an area that needs more study. Shifting to problem-based learning (PBL) is hard for teachers, as is integrating CT. Therefore, it is important to center this work on both the culture and needs of the community to get the buy-in to work through the challenges of PBL and CT. It is also important to ensure the value of each problem solving approach is maintained, the cultural significance of traditional (e.g. Appalachian) problem solving is maintained, and CT is not overgeneralized to the point of being disconnected from its computational roots. Clearly differentiating CT from complex problem solving, will serve as a starting point to help both keep the greater goals of complex problem solving and CT-specific problem solving as foci, and also help teachers develop scaffolds and protocols to develop these different skills.

Conclusion

We have sought to find ways for the culture of computing, centered largely in Western, educated, industrialized, rich and democratic societies (Henrich, 2020), to not inadvertently supersede the existing rich culture of Appalachia. In doing so, our project's broader culturally responsive lens aligns with Lachney's (2017) premise of culturally responsive computing as brokerage, or bridging two or more social worlds. By envisioning students as continuing a community legacy of problem solving, inheriting from family and teachers some precious place-based tools for their problem-solving toolkit (e.g. varieties of resourcefulness skills), and additionally fortifying their toolkit with new CT skills, we provide new possibilities for culturally responsive computing education. Culture is not only a context in which to learn computing or something to be brought in for engagement, but a way for students to expansively view the skills they and their ancestors have as complementary to new computing skills. In such a way, culturally responsive computing can go beyond surface level alignments and interactions between content and culture: Cultural capital and skills can be at the very core of what students are achieving in and through computing.

Acknowledgements

We are grateful to our colleagues Hobart Harmon, Roxana Hadad, Aman Yadav, Traci Tackett, Aileen Owens, Rusty Justice and the editors and anonymous reviewers for their comments and guidance on our draft manuscripts. We are also grateful to the broader Tough as Nails and Drawing on Kinship project teams, especially our partner teachers and administrators in Eastern Kentucky, for their strong collaboration and inspired co-leadership in this research practice partnership.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This material is based upon work supported by the National Science Foundation under Grant No. 1923314 and 2219401. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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