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How a child entangles empathy and computational thinking in reasoning about fairness

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abstract

In this work, we argue for expanding the scope of K-12 computational thinking (CT) integration contexts to include everyday scenarios involving moral reasoning. Epistemic overlap between computational thinking practices and moral reasoning suggest that these contexts are potentially rich sites to see “seeds of CT” in children’s reasoning and can provide rich educational pathways for children into CT. Taking a case-study approach, we examine the reasoning of a second-grader, Ollie, on a task involving fair allocation of resources to victims of a natural disaster. Our analysis finds that Ollie’s reasoning was rich with seeds of CT (e.g., problem formulation, abstraction, complex-systems thinking) and that empathy served as an important supporting role to the CT. This work has implications for curricular design, suggesting that fairness and resource allocation scenarios with built-in opportunities for empathy might provide rich sandboxes for CT integration.

1. Introduction

1.1. Seeing seeds of CT in children’s everyday reasoning

While debates around the nature of computational thinking (CT) still pervade the field of education research, many continue to recognize Wing’s core definition: computational thinking practices are everyday analytical thinking skills used to define and solve problems (Wing, 2006, 2008, 2011). Similarly emphasizing the “everyday” nature of CT, Furber conceptualizes CT as “the process of recognising aspects of computation in the world that surrounds us” (Furber, 2012). In differentiating thinking computationally from programming, Caeli & Yadav take this perspective one step further, arguing that the seeds of computational thinking are rooted in “human approaches to problem-solving” (Caeli & Yadav, 2020). This orientation toward CT suggests a possible pedagogical approach; noticing, naming, and nurturing seeds of CT practices in students’ everyday thinking (see Hammer & van Zee, 2006; Hammer et al., 2005; Warren et al., 2001 for a parallel pedagogical approach in science education) Fig. 1.

Seeing computational thinking as a refinement of everyday thinking (Einstein, 1936) helps keep educators and researchers grounded in the sense of reminding us where to look for seeds of CT. In particular, the “everyday” aspect of the perspective reorients us to center the life experience of the child, and phenomena and issues that are relevant to them. As educators, this perspective suggests a bottom-up pedagogical endeavor: sifting through children’s reasoning to find core seeds of computational thinking, in a way that reflects the situated nature of the reasoning and experience.

Another reason to search for seeds of CT in children’s everyday thinking arises not from the cognitive origins of CT but from the educational purpose of enhancing students’ CT. Although Wing and others argue that CT education is important for helping students problem-solve in both disciplinary and everyday contexts, the value of CT for everyday problem solving typically gets lost in curriculum development, assessment, and research (Shute, Sun, & Asbell-Clarke, 2017; Voogt et al., 2015). If we take seriously the idea that CT is useful for enhancing students’ everyday reasoning and problem-solving, then there is value in looking for seeds of CT in students’ everyday reasoning in *both* formal and informal learning contexts.

Taking the perspective that CT both draws upon and enhances everyday thinking, we are compelled to move beyond narrow visions of CT integration in STEM to a vision of pedagogy and design that draws in more everyday reasoning contexts . This especially includes contexts that invite children’s moral reasoning and computational thinking.

As we will illustrate with a case study of a 2[nd]-grader reasoning through a scenario about resource allocation after a natural disaster, contexts that invite students’ everyday reasoning—in this case, their intuitive moral reasoning, notions of fairness, and empathy—can comple-

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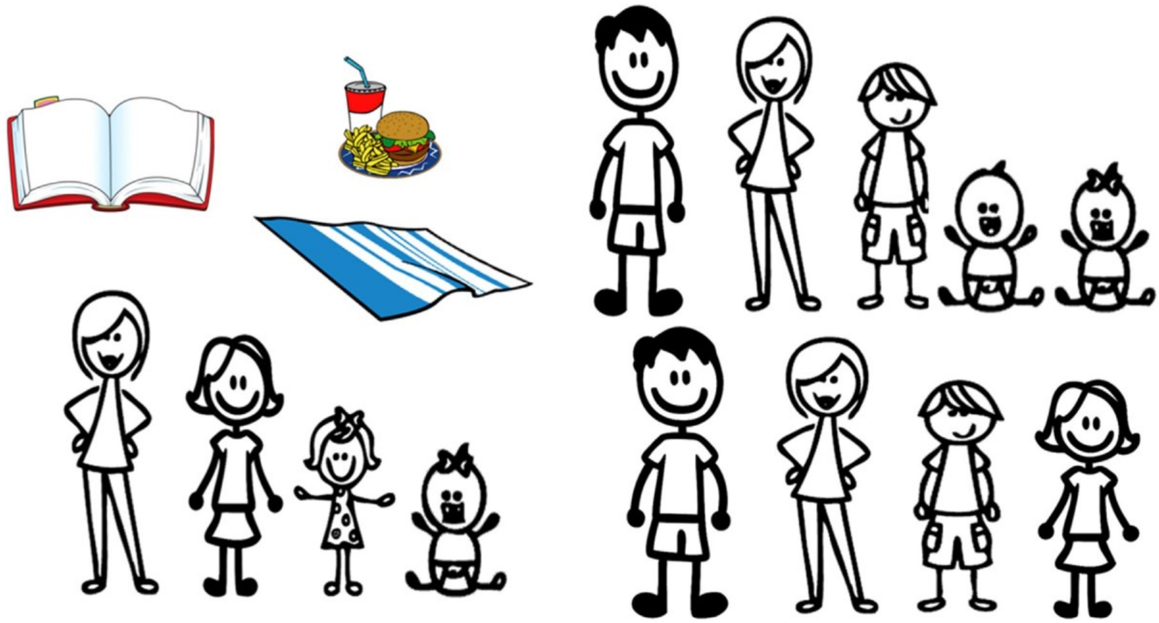

Fig. 1. Families and resources given out during the tasks. Interviewees were given two books, two blankets, and eight food cards.

ment and enhance STEM learning and CT while also creating meaningful points of contact between formal learning spaces and real-life contexts.

2. Background and motivation for this study

2.1. Epistemic overlap between disciplinary contexts and CT highlights the importance of introducing students to a breadth of contexts for developing CT

Integration of CT into other disciplines has become a focus in curriculum, instruction, and research. Such integration not only allows easier introduction to CT in early grades but also leverages the power of CT to enhance both learning and professional practice in other disciplines (e.g., Delyser et al., 2018; Lee & Malyn-Smith, 2020; Lee et al., 2020; NGSS Lead States, 2013; Prottsman, 2019; Sengupta et al., 2013). While Wing (2006) predicted that computational thinking approaches would become ubiquitous across all disciplines, most integration efforts have targeted programming, computer science, and other STEM fields (Hsu, et al., 2018). Many posit that STEM fields are “the ideal disciplines for introducing computational thinking concepts” (Henderson, 2009) because of the epistemic overlap across STEM and CT practices. Along these same lines, Sengupta et al. (2013) argue that certain synergies (i.e., epistemic overlaps) between computational and scientific expertise justify the integration of certain forms of computational thinking into science education. For example, the authors note epistemic overlap between the concept of “classes” in CT and agent-based reasoning in scientific inquiry. In agent-based reasoning, one would reason about “individual-level agents in a multi-agent” system. In computational thinking, one would similarly reason about the type or category (i.e., class) of individual objects being modeled and the associated properties that the class then confers upon the object. The authors argue that integrating computational thinking into science inquiry can help lower the threshold for learning certain science and math concepts by leveraging *intuitive* computational concepts or mechanisms (emphasis added, Sengupta et al. 2013).

Undergirding the identification of these contextualized CT/STEM practices is the recognition of “certain common features at the core of [the] problem solving and inquiry approaches” (Duschl et al., 2007). For example, the centrality of data in scientific and mathematical work underlie a category of CT practices revolving around computationally managing and manipulating data (Weintrop et al., 2016). Additionally, drawing on empirical work, these authors note the reflexive connection between CT and STEM content: thoughtful integration can deepen learning of both (e.g., National Research Council 2011; Sengupta et al. 2013; Wilensky et al. 2014).

These arguments about the productivity of CT-STEM integration have, to a large extent, led the field of CT education to narrow its focus to STEM contexts. This coupling, however, has unintentionally created a chicken and egg problem. We look for CT in narrow contexts and find narrow practices, which then narrows the field further as researchers debate the intricacies of CT within that narrow set of contexts (c.f. Gupta, 2017, for a similar argument in the context of science inquiry). Our point in this section, however, is that CT-STEM integration is productive largely *because* of the epistemic overlap between STEM ways of thinking and CT. This argument invites a search for *other* ways of thinking that display epistemic overlap with CT—and hence, new possibilities for integrating CT and those other ways of thinking. This insight has important implications for the design of learning environments intended to nurture and assess CT. The learning contexts we design to nurture and assess CT are coupled with what we will nurture or find. Therefore, expanding beyond STEM the range of contexts in which students explore CT will allow designers to create a richer variety of educational experiences around CT, linked to a richer, more multifaceted conceptualization of CT itself.

2.2. Expanding beyond an overly narrow focus on CT concepts can have important pedagogical affordances

In the previous section, we argued for the productivity of expanding CT education in the sense of expanding the range of contexts into which CT is integrated. In this section, we argue for another kind of expansion of CT education—one more expansive in attending to the heterogeneous nature of CT itself and what counts as experiencing it.

Central to the CT education movement have been efforts to define core CT practices in ways that are decontextualized. By “decontextualized,” we mean broadly applicable across grade levels, topics, task structures, and other contextual features of the learning environment. Such decontextualized definitions of CT often consist largely of CT concepts such as “decomposition” and “conditional logic” and CT practices such as “debugging,” often summarized as lists. This decontextualized conceptualization of CT has correspondingly led to learning environments and especially assessments that focus mainly on supporting and assessing students' engagement with CT concepts and practices (Tang et al., 2020; Hsu, Chang, Hung, 2018). While this work has helped bring coherence to the field, some educators have begun to push against what they see as an overly narrow focus on decontextualized practices (Weintrop et al., 2016; Sengupta et al, 2021) and CT concepts (Sengupta et al, 2021; Tedre & Denning, 2016). At first glance, it may seem appropriate for the field to focus mainly on cohering around lists of central disciplinary practices and concepts. However, expanding beyond discrete, disconnected practices and concepts can have important pedagogical consequences, encouraging the field to expand the ways in which we think about CT in relation to the heterogeneous nature of experience and learning (Sengupta, et al, 2021).

Drawing on Bakhtin's (1981, 1984) notion of heteroglossia, Roseberry and colleagues have demonstrated that heterogeneity is fundamental to learning, showing that everyday and disciplinary perspectives can productively come together to support students in understanding disciplinary perspectives on science concepts (Rosebery et al, 2010). Similarly, Sengupta, Dickes, and Farris (2021) stress the importance for educators and researchers to attend to the heterogeneous nature of computing, recognizing that students' learning of computing can have a holistic nature. Specifically, Sengupta and colleagues argue that computational concepts are relatively meaningless for students and researchers alike, and these concepts take on meaning as they are recontextualized in new phenomena and new experiences. Experiences of computing are heterogeneous in nature, involving aesthetics, emotions, and the coordination of diverse perspectives. Sengupta and colleagues (2021) further highlight the *pedagogical* value of recognizing and supporting the heterogeneity of computing experiences, not just the "underlying" CT concepts. Supporting the heterogeneity of computational work in classrooms can not only support students in developing models but also support teachers in developing "computational voices" (Sengupta et al., 2021).

2.3. Moral Reasoning involves a complex coordination of relevant features, relationships, and group processes — which has epistemic overlap with computational thinking

We draw on socio-cultural perspectives of moral reasoning and development that recognize the ways in which moral reasoning is shaped by its specific socio-cultural and historical context (e.g., Tappan, 1997; Tappan, 2006). In particular, Tappan draws on Bakhtin and Vygotsky to highlight ways in which moral development and reasoning are dialogic in nature, mediated by language and tools (Tappan, 2006). Like Sengupta and colleagues in CT, these socio-cultural turns entail attending to mediated action, or experience, recognizing that moral reasoning goes beyond cognition and/or emotion, but entails both and more. Discourse is, of course, one mediating mechanism and Tappan's Bakhtian influence guides us to expect heterogeneity in moral reasoning. Moral reasoning is agentively woven together from the cultural material available, with the child making judgements about which materials are appropriate (a form of abstraction) and how they fit together. While culturally dominant norms/views certainly exist, these perspectives help us notice and expect the construction of divergent meanings, which are "associated with particular roles within specific cultures" and can reproduce or contest powered relations in those cultures (Wainryb & Recchia, 2013). Work by Gilligan and colleagues has demonstrated that children make sense of moral conflict by coordinating two different discourses, a justice voice and a care voice. The first is concerned with not treating others unfairly and the second is concerned with responding to others in need (Gilligan et al, 1988). Both voices come into contact through internal and external dialogue as the child makes sense of the conflicts. Furthermore, both voices have significant power/privilege associated with them related to the gendered patterns in how they are sometimes enacted in reasoning. This socio-cultural orientation points to the importance of (i) attending to the discursive processes of children's meaning-making, not just the moral judgements they come to; and (ii) recognizing that the values and perspectives brought to bear, and the meanings made from them, will vary not just across different children but also within the talk of a single child.

Children demonstrate significant flexibility in their moral reasoning and development as they "weigh and attempt to coordinate concerns with autonomy and rights, with group goals, harmony, and tradition, and with human welfare and justice, thus arriving at varied understandings as they construct meanings about the wide range of experiences that they encounter in their everyday lives" (Turiel, 2002). A focus on the complex coordination (Rizzo & Killen, 2016; Turiel 2002) children do as they construct notions of fairness can begin with recognizing how children abstract and coordinate relevant features, values, and relationships in a complex situation. For example, school-age children tend to construct different notions of fairness depending on the type of resource being distributed (e.g., luxury or necessary) and on ascribed features of the people receiving the resources (e.g., hardworking or lazy) (Rizzo et al, 2016). Similarly, 7 to 8 year old children recognize inequalities among people and construct distribution schemes that rectify those inequalities (Fehr et al, 2008; Elenbaas & Killen, 2016). Additionally, older elementary school children incorporate *both* productivity and physical advantage into their reasoning (Thomson & Jones, 2010).

Indeed, children can go beyond coordinating different ascribed attributes of individual people into their reasoning. They also begin to incorporate considerations of group norms and processes. For example, children demonstrate increased ability to reason about social acumen in the context of group norms or processes when evaluating equal/unequal distributions (Rutland & Killen, 2015). With age, children begin to favor equal distribution of resources in spite of group norms of unequal distribution and group bias against deviance from norms (Hitti et al, 2014). In summary, children's moral reasoning about fair resource distribution displays epistemic similarities to CT: from messy reality, children tune into features that describe individual agents (people), group those agents into categories, articulate relationships between agents and/or classes, and characterize processes describing interactions between agents and/or categories. In the section below, we highlight the similarities between these forms of moral reasoning and forms of computational thinking.

2.4. Children's moral reasoning around fair resource allocation has significant epistemic overlap with CT practices

We now reach the punchline of the argument set up by the previous subsections. Reasoning about fair resource distribution involves the extraction from messy reality and the complex coordination of relevant features, relationships, and processes describing and connecting agents and groups of agents. This particular form of knowledge generation and manipulation, we now argue, has significant epistemic overlap with CT practices. Therefore, children's moral reasoning around fair resource allocation has significant epistemic overlap with CT.

We now summarize some ways in which the "complex coordination" children do when engaging in moral reasoning epistemically overlaps with CT.

- Problem formulation (Wing, 2006; Wing, 2008; Wing, 2011; Cuny et al, 2010; Aho, 2012) involves "formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (Cuny et al, 2010). Problem formulation necessarily involves abstraction (Brennan & Resnick, 2012; NRC 2010; Weintrop et al. 2016; Wing, 2006). In the context of fair resource allocation, this involves modeling what is needed and what is available, in order to set up the task as one of distribution based on coordinated needs and resource availability.

- Complex systems thinking (Shute et al, 2017; Weintrop, et al. 2016; Sengupta et al., 2013) involves constructing relevant categories or classes in the system (Sengupta et al., 2013), modeling the interrelationships between different parts of a system, and moving between micro- and macro-levels of reasoning.

We'll revisit the epistemic overlap of moral reasoning and computational thinking after presenting our case study, which provides a particularly strong example of such overlap.

In summary, we've argued that there are both psychological and pedagogical reasons to search for seeds of CT in pockets of children's everyday thinking, and that moral reasoning about fair resource distribution is a potentially fruitful pocket to explore.

3. Methods

In this section, we lay out how and why we designed the resource-allocation task, how we conducted the interviews around this task, why we selected "Ollie's" interview for deeper analysis, and how we carried out the analysis using fine-grained discourse analysis. As noted above, this case study is meant to illustrate the epistemic overlap of moral and computational thinking and to provide an initial, exploratory look at a child's reasoning about the task.

3.1. Task Design

We organize our description of how we designed the task around the various task affordances we were trying to create: conceptual, material, interactional, and epistemic overlap with CT. Instead of also presenting a monolithic positionality statement, we discuss within each of these subsections how our positionality affected our choices.

Conceptual: Drawing on the literature around fairness of resource allocation, we designed an interview scenario for elementary school students in the U.S. We intended the task to leverage existing intellectual abilities some children tend to exhibit in this age group, such as differentiating notions of fairness based on type of resource, while also allowing children to construct a situated, flexible meaning of the scenario. In the scenario, a hurricane in a town has forced three families to relocate to a shelter. The students and interviewer have resources represented on cards—books, blankets, and food—to distribute to three families in the most fair way possible. The three families have different numbers of babies, younger kids, older kids, and adults. We chose the number of resources such that it is not possible to allocate one book or blanket per family (there are two of each) or one food per person (there are 8 cards of food and 13 people). The combination of scarcity, different types of resources, and different family make-up is meant to create a scenario where kids are able to develop notions of fairness based on the intricacies of the situation.

Material: We designed the task with specific material affordances to support flexible reasoning. The manipulatable nature of the resources and families, as represented on cards, we hoped would enable the interviewer and child to readily "see" and interpret quantitative relationships—for example, how food allocation compares across families. The manipulatable nature of the cards given to students, along with their visual affordances, we hoped might enable quick debugging based on quantitative interpretations. This can lead to rapid reallocation of resources based on emerging notions of fairness.

At the time, we did not consider the cards' representations critically. In hindsight, we notice that the tasks depict heteronormative notions of "family." These representations can invisiblize the struggles of LGBTQ+ communities during disasters (D'Ooge, 2008). Similarly, the human icons in the task cards can appear as white. In the future,we need to be more intentional about the representational aspects in the design of cards for such tasks—not just for the representations of humans, but also for the food and books, which are cultural.

Interactional: The interviewer approached these interviews as semi-collaborative, with the interviewer there to support sense-making (e.g., by providing emotional support, distributed memory, clarifying questions, etc.). This included supporting children in extending the scenarios in whatever way the children saw fit. So, there was no interview protocol, beyond the interviewer presenting the scenario and then drawing out the participant's reasoning.

Overlap with Computer Science K-12 Standards: The design and facilitation of the task is intended to overlap with several grade-level Computer Science standards (CSTA, 2017), including:

- 1A-AP-14 Debug (identify and fix) errors in an algorithm or program that includes sequences and simple loops. (P6.2)
- 1A-AP-11 Decompose (break down) the steps needed to solve a problem into a precise sequence of instructions. (P3.2)
- 1B-AP-13 Use an iterative process to plan the development of a program by including others' perspectives and considering user preferences. (P1.1, P5.1)

3.2. Case study selection and approach: Ollie

We conducted seven video-taped interviews with children in 2nd through 4th grade. The interviews were conducted in English. In the school district where the interviews took place, 13% of the students identify as white, 62% identify as black, 18% identify as Hispanic or Latino, 4% identify as Asian, and 2% identify as two or more races. 26% of children five years and older speak English very well, 65.6% speak English only, and 8.4% speak English less than well. 9.5% of families in the district live below the poverty level and 16.8% have food stamps benefits. The interviewer was a white cis-gender woman in her early thirties, with US-English as her first language.

These interviews were exploratory in the sense that we were not seeking to test a well-defined hypothesis, but rather to (i) explore our rough conjecture that moral reasoning around scenarios involving resource allocation can potentially provide rich contexts in which seeds of CT become apparent in young children's reasoning, and (ii) clarify what some of those "seeds of CT" look like in this context, to guide future exploration and hypothesis generation about how those seeds can be elicited and nurtured. So, we don't aim to describe what is normative or average in terms of childrens' reasoning. Instead, we focus on a single interview with 7-year old "Ollie," who initially struck us as displaying exceptionally rich reasoning. By analyzing Ollie's reasoning in depth, as described below, we aim to flesh out what seeds of CT appear in his reasoning and how his emerging computational thinking and moral reasoning are entwined. We also begin to identify what resources—internal cognitive and affective resources and external socio-material resources—support Ollie's reasoning. Understanding how and why Ollie's reasoning (CT and otherwise) is particularly rich can inform not only future research, as noted above, but also the design and facilitation of lessons and learning environments that help young children, over time, activate and build on the seeds of CT that appeared relatively quickly for Ollie (i.e., in a single short interview).

What does it mean for us to select Ollie from our data corpus as representing "rich" reasoning and to highlight the stories that Ollie tells in this paper? Our choices reveal the researchers' own positionality. Ollie presented as white and fluent in English. This was in contrast to some of the other children interviewed who were Latina/o and spoke Spanish at home. We did not have any Latina/o researchers on our team, or folks who were fluent in Spanish. Within our dataset, Ollie stood out as remarkably confident in his responses, and explained his reasoning in depth. Long articulated responses lend better to the text-based analyses in which the research team is proficient and comfortable. But we also expect that what we notice as "rich reasoning" reflects race, class, and language alignments between interviewer and interviewee, which can create contexts in which particular children come across as more articulate. Our selection, therefore, likely reflects these biases. This does not deny that Ollie was articulate, but it should limit our (and readers') interpretation of this selection as rooted in that. And this limitation exhorts us, in future, to invest in methodologies that iteratively refine the design of interview contexts, selection of interviewers, and interview prompts, towards creating opportunities for rich creative explorations by students from non-dominant backgrounds.

3.3. Who is Ollie?

Children for the interview were recruited through elementary teachers who worked on a professional development project with the authors focused on examining how computational thinking can support reasoning about socio-scientific issues. Ollie (7 years old) attended a public elementary school (PK-5th grade). The school had approximately 600 students total, with around 30 students in Ollie's class. Ollie's interview took place at the end of his 2nd grade year on the 2nd to last day of school during the school's 30-minute breakfast period. The class was very relaxed and fairly quiet watching announcements and eating breakfast, while the interviewer (Erin Sohr) and Ollie sat at a table in the back of the classroom. The interviewer had visited Ollie's classroom once before, but the interview was the first time that Ollie and the interviewer spoke. Both are white and US-English-speaking. Ollie and the interviewer present as a boy and woman, respectively.

Throughout the interview, Ollie explicitly drew on his previous experiences to support his reasoning about the task. The interviewer often used these moments to learn more about Ollie and his background. Ollie exhibited a significant amount of reasoning about the needs of the babies and smaller children in the scenario. Ollie, though an only child, explained that he grew up with other kids, having gone to daycare for "5 years of his life" where he was around smaller children. When he was a toddler, he moved from a city several hours away to the town where he lived at the time of the interview, both homes located in the Eastern part of the United States. When asked whether he had personally experienced a hurricane before, which he had not, he did share that his family had experienced a flood that damaged their home and an earthquake that turned their home into a "big pile of rubble." Drawing in these various experiences, in part, supports the richness of Ollie's reasoning about the scenario.

3.4. Analytical flow

Overview: We take a microgenetic approach to modeling Ollie's reasoning in order to capture any quick changes in the reasoning. These changes could consist of subtle or not-so-subtle shifts in how the resource-allocation task is framed, and/or shifts from one method of fair distribution to another, and any intermediate proto-conceptions of fairness (Siegler & Crowley, 1991; Parnafes, 2013). This modeling of Ollie's reasoning involves mapping the coordination of different communication channels, such as speech, gesture, and manipulation of material artifacts, in order to describe the notions of fairness (and related reasoning) that Ollie generates and the interviewer supports (Goodwin, 2007). This analytical work includes modeling what stabilizes or destabilizes the different notions of fairness (or related conceptions) that Ollie constructs (with the interviewer) through the interview. As we will discuss more below, empathy, which we take to have both cognitive and emotional dimensions, is one mechanism that seems to stabilize and destabilize Ollie's different notions of fairness. While the connections between empathy and moral reasoning seem to have become fairly well-established in the early childhood development literature (e.g., Malti & Ongley, 2013), the connection should not be taken for granted or viewed ahistorically. More widely recognizing this connection was part of a movement to recognize more diverse, feminist discourses in moral reasoning (Gilligan, Ward, Taylor, Baridge, 1988). And so, when we view moral reasoning through a lens of CT, with our socio-cultural orientations to both CT and moral reasoning (as described above), it's imperative not to silence the different discourses known to be a part of moral reasoning.

Developing a "thick description" of the interview: Our first pass through the data develops a thick description (Geertz, 2008) of events and reasoning, paying careful attention to any conceptualizations of fairness, justifications for proposed resource distributions, and enactments of associated distributions. Centering the different notions of fairness in Ollie's reasoning provides a natural parsing of Ollie's interview into different sections, as presented below. This parsing corresponds to a coarse-grained description of Ollie's reasoning, which informs the patterns that we glean from the interview (described below). We present the entire thick description of the interview before discussing analytical patterns, in order to preserve the storytelling that Ollie does in the interview.

There are many ways we could have fleshed out this thick description. The particular emphasis we have chosen reflects our own disciplinary positionalities. The project team members, including those who are not authors on this particular manuscript, have been invested in writing and thinking about computing education to varying degrees, with some strongly invested in it. Some of us have also been invested in research on moral and ethical reasoning in engineering contexts. The first author audited a course on children's moral reasoning to support this work, and that added knowledge from psychology of children's morality to our thinking. Thus we do not feel that it is a happenstance or any "carving of the data at the natural joints" that this analysis comes to focus on how CT and moral reasoning are entangled in children's reasoning. We struggled extensively about whether trying to "analyze" Ollie's reasoning through a CT lens makes any sense. Ultimately, we convinced ourselves that doing so would contribute to expanding our notions of what CT is and what it can be, making it worthwhile. While we have tried to represent Ollie's voice holistically, in retrospect, we also see our analysis as drawing on somewhat reductionist thinking, extracting and highlighting particular aspects of CT and moral reasoning in Ollie's utterances. We feel that this reductionism tacitly arises not just from our long-term association with research on computing education but also from our academic histories in physics and engineering.

Applying CT and empathy "lenses" to the thick description to determine salient patterns: After Ollie's storytelling, we then apply CT- and empathy-lenses to the data. As described above, aspects of CT we might expect to see through a CT lens include problem formulation, abstraction, and complex systems thinking, including constructing classes in the system.

According to Batson (2009), empathy is the ability to know how another thinks and/or feels, and is, relatedly, the ability to "respond with sensitivity and care to the suffering of others." Batson and other scholars (e.g., Hess & Fila, 2016) have taken this framing and defined specific aspects of empathy. Some of the most relevant to our data include concern for another (either positive or negative emotions/responses), perspective-taking, and projecting, i.e., "imaging how one would think or feel in the position of another" (Hess & Fila, 2016).

By "applying a lens" to the data, we do not mean coding for CT and empathy. Rather, we mean attuning ourselves to "see" elements of these constructs in a way that enriches the description of Ollie's reasoning rather than functioning as a decontextualized "analytical layer" on top of the rich description. For this reason, we draw on the CT practices and forms of empathy described above as sensitizing concepts (Bowen, 2006) which direct our attention to relevant moments in the data; we then rely on the situated nature of the reasoning to recast the interaction in terms of seeds of CT and empathy. So, in representing what we see through these lenses, we try to emphasize or retell aspects of the story of Ollie's reasoning in ways that remain true to his meaning, rather than just imposing labels on his utterances.

This approach emerges, in part, from our conceptualization of these practices as situated and therefore suffused with local epistemic flavor and purpose—which implies that the seeds of CT might appear in variegated and unfamiliar forms. With the data parsed through CT and empathy lenses, we can then describe relevant patterns in the reasoning.

4. Results

4.1. Data and initial analysis

Below, we present thick descriptions of the data. In presenting the transcript, gesture and non-verbal moves are described in double parentheses. Then, we step back and retell parts of the story by viewing it through CT and empathy lenses.

1. Blankets for babies.

Ollie starts by distributing the blankets to the babies, saying "cus they really need it[...] cus all of the other people are older," as he lays the blanket cards over the babies. Prompted by the Interviewer to say more, he explains that older kids have more experience dealing with cold:

> Ollie: So, the babies need more warmth, to survive, they haven't been through such as, such stuff as this. And these kids are older and they might have been camping out and they might have seen and, experience of some people, like when they're camping, they don't have any blankets, so they would have to sleep out just to...
>
> Interviewer: So maybe the babies aren't used to, and the young kid, is not used to being comfortable ((Ollie adjusts blanket on babies to leave their heads out)), yeah, in cold. Hmmm.

As Ollie carefully adjusts the blanket cards on the babies so that their heads don't get covered by the blankets, we get a feel for the gravity and attention that Ollie is giving to this task, an orientation that continues throughout the interview.

2. Distributing food: Sharing in light of scarcity.

After distributing the two blankets, Ollie starts distributing food, from left to right saying "food, food, food" liltingly as he places one food card on each person. Midway through, when there are two food cards left and seven people without food, he looks back-and-forth between the resource pile and the remaining people yet to get a food item. He skips an older kid and places a food token on one of the babies of the family. After thinking for a bit "hmmmm," he takes food off of the Mom and Dad of the middle family and looks around again. After he places a food unit on the last baby, the interviewer asks him to explain his thinking. He explains the redistribution:

> Ollie: Well if the babies don't have food, if the babies don't have any then nobody's gonna be happy. It's like they're just gonna whine and cry and it'll be very frustrating. So I'm gonna give food to this kid. They have a lot. And this family can share two piles. Because this family is the biggest, they should have the most food, because they have to care for more.

Here, Ollie's initial distribution of one item per person conceptualizes each person as identical and individualized entities, regardless of them being a baby, child, or adult. In response to discovering the scarcity of food, he fleshes out a redistribution that configures the persons differently. Ollie articulates how addressing the needs of particular individuals affects not only those individuals but also others, thus putting them in relation with one another. As individuals are connected within family units, sharing emerges as a way to think about the food distribution. Simultaneously, Ollie starts accounting for the inequality in the food available to each family unit, drawing on the differences in the sizes of the family units.

3. Adults read to the babies, physical proximity allows sharing and requires reinscription.

Ollie holds the two books in his hands and looks across the families. For the two families with babies, he places the book cards between the two adults in one family, and between the adult and oldest child in the other. He explains that "most babies like being read a story before they go to sleep." Like his distribution of the blankets, Ollie places the resource as it would be used by the people—the adults have the books because they would read to the babies. And then Ollie suggests a very different alternative:

> Ollie: And you know what? An idea popped into my head: if the families live near each other, then they could get along and share their stuff between them.

Ollie's new idea of sharing *between* families has opened new possibilities for resource distribution. Ollie then explores how the families could share books, blankets, and food, especially towards supporting the family with the least amount:

> Ollie: Actually, they could lend them a blanket for a little while, for a couple, for a day, and then the mom could snuggle up next to the babies, so yeah. And then they could give them some of their food, and then they all would be sharing.
>
> Interviewer: So it seems like you're saying this family and this family would give some stuff to them?
>
> Ollie: Yeah, cus they have the least stuff.

In this new scheme, some collaboration or coordination between individuals is required to enable sharing across families; in this case the mom snuggles the babies to make up for the loss of the blanket.

4. If the shelter is in a hot place, water should be available for people to drink.

After a bit of silence, Ollie brings up the question of where the shelter is located and how that might influence the comfort and needs of the people:

> Ollie: Well I was just thinking, I was wondering, I wonder, where is this shelter? If it's in a dry place, then they should have a lot of water to drink.
>
> Interviewer: Oh, so that's something else they need?
>
> Ollie: Like food and water.
>
> Interviewer: Can you tell me a little bit more about that? What made you think about that?
>
> Ollie: So if it's very hot, and it's steamy where they're staying, the baby might not like it, and it might be a little uncomfortable for all of the families.
>
> Interviewer: Oh, ok. Somewhere like a desert or something?
>
> Ollie: Yeah, if they were staying in Texas or somewhere like that.
>
> Interviewer: Have you ever been to Texas?
>
> Ollie: No.
>
> Interviewer: Oh, ok. Cus it's hot there.
>
> Ollie: I hear that it's hot there.
>
> Interviewer: So you were saying we need some water to share? Right? So how would we share the water in a way that's the most fair?
>
> Ollie: As I was saying, the babies don't need that much water because they're very small, and they only need their mom's milk, so they could give some of their water to this family.

Ollie again continues to create a more detailed scenario when he begins to wonder where the shelter is located. Ollie and the Interviewer imagine the experiences and needs of people, if the shelter was in a hot place such as Texas. Recognizing that they would need water raises the issue of fair distribution of water. And as before, Ollie attends to not only the differential needs of the different people but also the relationships among the different people and how that could enable sharing of water *between* families. Again, the care that the moms can provide the babies serves as a type of resource; leveraging this relationship allows resources to be freed up for others. This idea of seeing the families not as individual units, but as connected and potentially sharing resources during this disaster, continues throughout the interview.

5. Zooming out: personal experiences inform empathic reasoning (babies) and reflecting on the difficulty of the scenario through storytelling.

In the next segment of their conversation, Ollie and the Interviewer reflect on the scenario and their reasoning for distributing books, blankets, food, and water. In doing so, Ollie draws on his personal experiences at daycare to justify prioritizing blankets for babies: "I know babies cus I've grown up with kids my whole life."

Ollie reflects on the difficulty of the task:

Ollie: This isn't like staying in a hotel, this is hard trying to find out what to do.

Interviewer: What makes it so hard?

Ollie: There's a lot going on, and there's a lot of people. It's just, really hard to do.

Interviewer: When you say there's a lot going on, what do you mean?

Ollie: So these families have been through a lot, they've been stressed, they're scared, they've been pushed around by the wind and the bricks in the air. They just need a break, they need to cool down. Relax.

Interviewer: We need to take care of them.

Ollie: Yeah. Especially the littler kids, cus the parents might have experienced this already, if that's like a hurricane area.

Ollie connects the difficulty of the task for him to caring for the families who have "been through a lot." Here too, Ollie orients to the potential experiences of the people at the shelter and their emotional needs.

6. Reflecting on & debugging food distribution based on moms nursing babies.

The interviewer next invites Ollie to reflect on whether the current distribution of resources was fair, whether the families facing the disaster might think something is unfair, and if so, how would he respond. Ollie says that the family with lesser food cards might say this is unfair. Ollie tries to explain why this distribution might be unfair from the perspective of the family with only 2 food cards: Noting that the babies will likely only consume milk from the mom, the family with 3 food cards is unlikely to need it all. He redistributes the food to the family with no babies as the more fair thing to do. As Ollie and the interviewer continue to play out this scenario, however, he becomes less certain of this action. Neither Ollie nor the interviewer feel certain they know how much food a mom might need, when she is also nursing the baby. Together, the interviewer and Ollie consider the case where mom needs a little and a lot of food. Ollie operationalizes a little and a lot as half and a whole food card per baby for mom. In each case, Ollie redistributes food based on the different needs of the moms. In the case where the mom needs "a lot" of food, the mom with two babies gets two food cards, and the mom with one baby gets one food card. In the case where the mom needs a little, the mom with two babies gets one, and the mom with one baby shares her food card with another kid in the family.

Towards the end of this segment, Ollie expresses that the task of optimizing the distribution of scarce resources was hard and "a little bit stress[ful]" to decide what's best for the families.

4.2. *Analysis of patterns in the reasoning*

4.2.1. *Fairness*

Through the interview, Ollie drew on various notions of fairness. Some of these notions were implicit in the distribution strategies that Ollie regarded as appropriate or just. At other times, fairness was discussed more explicitly. Right from the start, prioritizing distribution of blankets to babies, Ollie took the physical and emotional needs of people into account to articulate what would be fair. Implicitly, here, fairness was constructed in terms of attending to the needs of those group members who were most vulnerable. By contrast, when distributing food, initially fairness was constructed as treating everyone equally: every person got 1 food card. However, scarcity of resources made this unfeasible. In response, Ollie again prioritized babies, but with a significant difference in reasoning. This time, the justification was based on the overall happiness of a group of individuals: the notion of fairness shifted from individual equality to optimizing well-being at the group level. These different notions of fairness often involve perspective taking and modeling group processes. In particular, his notions of fairness and his corresponding distribution schemes occasionally require the people in the scenario to attend to the physical and emotional needs of others. This way of reasoning binds the people in mutual interdependence, within and across families, rather than casting them as a collection of individuals. The notion of fairness shifted again as Ollie tried to understand the perspective of families who received fewer total food cards than others. Here fairness again takes on notions of equality, but at the group level rather than the individual level. These shifting notions of fairness were coupled with computational aspects of Ollie's reasoning, as we argue next.

4.2.2. *Computational thinking*

Earlier, reviewing prior theoretical and empirical work, we argued that there are epistemic overlaps between psychology researchers' descriptions of children's reasoning about fair distribution of resources amongst individuals or groups and CT education researchers' descriptions of children's computational thinking. The overlap made us optimistic that, in our interviewees' reasoning about the hurricane scenario, we would be able to locate seeds of CT practice, such as problem formulation, abstraction, classes/categories, and complex systems thinking (coordinating micro- and macro-perspectives). When we look at Ollie's reasoning through the lens of CT practices, we can indeed see these seeds emerging in a connected fashion.

Throughout the interview, Ollie *abstracted* relevant properties of people and of resources which helped him re*formulate the scenario.* For example, as Ollie started distributing blankets, he labeled two of the people as "babies" and "older people," based on their prior experiences with the cold. The "data" in front of Ollie was categorized into specific "classes" relevant to the resource to be distributed, blankets. Thus the "computational problem" itself was transformed from an arithmetic distribution to one that is socio-technical, taking into account the human needs. This enabled Ollie to think about a fair distribution of blankets as one that took into account the specific vulnerabilities and tolerances with respect to cold.

On the other hand, as Ollie began distributing food, he initially approached the task as allocating one-per-person, an arithmetic task. All persons were implicitly framed as identical individual entities, making it fair to give each person the same amount of food. However, Ollie soon realized that there is not enough food for this distribution algorithm. This recognition of scarcity made Ollie change his strategy to distinguish, again, "babies" from "older people" based on their behaviors in response to food scarcity. In doing so, the "computational" problem got re-formulated as one that infused arithmetic with social aspects. This was coupled with Ollie thinking about a fair distribution as one that would lead to the overall happiness of the group (avoiding babies becoming "cranky"). Towards the end of the interview Ollie again revisited this strategy, when asked to evaluate the fairness of the distribution from the perspective of the displaced families. Noticing that one family with two "babies" has more food, Ollie redistributed the food cards, arguing that the "mom" could nurse the babies and so the babies do not independently need food distributed to them. The labels of "babies" and "mom" also reemerged here. However, this strategy became contingent on knowing how much food the "mom" needs in order to effectively nurse the "babies." Supported by the interviewer, Ollie started thinking about how the strategies would play out under two possible cases: *If* a mother needs a lot of food to make milk, or *else if* she does not. Here we see how the CT practices of forming classes of entities, abstraction, problem formulation, and case-based reasoning were coupled with evaluating and redefining fairness and reformulating distribution strategies.

At various moments, Ollie coordinated between the individual-level ("mirco"-) and group-level ("macro"-) of the system. For example, Ollie argued that if the "babies" (micro-level) were hungry, they would lead to broader unhappiness for the other people in the shelter (macro-level). This leads Ollie to reformulate the distribution strategy: allocate food to babies first, and then have the rest of the people share what is left over. The evaluation of fairness of distribution of resources happened at these multiple scales, sometimes at the level of individuals, other times at the level of a group of individuals ("family"). The back and forth between these scales leads to the emergence of new relations between entities: sharing of food and other resources within a family unit, sharing between families, and more complex connecting links such as mothers consuming food and then generating food for the babies.

4.2.3. Relationship between computational thinking and empathy

Throughout the interview, Ollie reasoned about how the people in the scenario might be thinking and feeling. Ollie frequently expressed concern for them, and this concern often guided his strategies for resource distribution—strategies whose formulation relied on CT, as argued above. Most often his empathic stances came in the form of perspective-taking (imagining how others are thinking and feeling), expressing concern, and projecting (imagining how he would feel in the scenario). Babies were of particular concern for Ollie; he returned to them throughout the interview. He thought carefully about how the babies might be feeling and reacting to the circumstances. For example, right at the start, Ollie thought about how the babies might not be accustomed to cold and so needed greater protection from cold; or, later, about how hungry babies would be "cranky" and cry, leading to other people being frustrated. This then shaped how other people were constructed, the local meaning of a particular resource, and relevant relationships and interactions between the different people.

These instantiations of empathy informed Ollie's decisions about resource allocation and notions of fairness in ways that are connected to Ollie's computational thinking. For instance, empathy toward the group as a whole motivated the reallocation of food to make sure the babies aren't cranky, a redistribution that relies on complex systems reasoning and notions of "classes" of individuals.

As the interview nears its end, Ollie reflects on the task and the people in the scenario. Ollie imagines the perspectives of the people in the scenario to describe their physical and emotional well-being ("pushed around by wind and the bricks," "stressed," and "scared") and expresses empathic concern towards their conditions.

> Ollie: So these families have been through a lot, they've been stressed, they're scared, they've been pushed around by the wind and the bricks in the air. They just need a break, they need to cool down. Relax.
>
> Interviewer: We need to take care of them.
>
> Ollie: Yeah. Especially the littler kids, cus the parents might have experienced this already, if that's like a hurricane area.

Ollie took the task seriously, carefully thinking through the different distribution algorithms and revising them in light of new information. In the process the problem gets reformulated, and new relations emerge between entities. In part, this is made possible due to Ollie's consistent empathic orientation towards the task, which enables him to develop details of the scenario that were not included originally.

4.2.4. Relationship between empathy and storytelling

Ollie's empathic stances are often not just asides but serve a central function in his reasoning. Empathy helps explain why the task was so consequential to him, and maybe why he took it so seriously. In addition, Ollie's empathic statements often added relevant information or context to the scenario, through storytelling, which was consequential for recontextualizing the computational thinking practices that we outlined above. For instance, Ollie's projection of how babies versus older kids and adults might cope in the cold helps create the sense that he is not simply distributing resources amongst different categories of entities; he is distributing necessary goods amongst people who have histories and experiences that matter, such that they are in relation with one another in a way that they would want to cooperate and attend to each others' needs, which is crucial for this distribution to work amicably. Importantly, Ollie's storytelling does not happen in a vacuum; it is a joint accomplishment between him and the interviewer, who collaborates with Ollie and invites him to add more details to the scenario. This storytelling transforms the two-dimensional cards into multi-dimensional people who have feelings and relationships with one another, people capable of cooperating and sharing, who can supplement the provided resources with other resources they might have brought themselves (such as jackets), people with individual and collective physical, intellectual, and emotional needs and relational responsibilities.

5. Discussion

5.1. Our exploratory study informs future research

Ollie's interview makes visible several features of the scenario design and facilitation that we believe may support rich CT reasoning. We will use these as starting points to inform future research and design efforts.

Fairness of resource allocation scenarios as productive contexts for CT reasoning: From Ollie's interview, we see evidence that resource allocation, particularly when resources are scarce or not evenly divisible across units of people, can invite reclassing. As discussed above, the limited supply of food, blankets, and books invited Ollie to reformulate a purely arithmetic task into a more complex computational task requiring him to reinscribe once-identical individuals with distinguishable labels which took into account needs, preferences, feelings, and relationships. This process involved running multiple algorithms, debugging, and iteratively testing different configurations of coordinating classes. Going forward, we hope that we and other research groups will refine and explore conjectures about whether and how sufficiently complex resource-allocation tasks elicit the CT seeds of *reclassing*, which then in turn leads to activation of other seeds of CT.

Layering empathy and collaborative storytelling as explicit features of the scenario design and facilitation: While the fair resource allocation scenario sets up some of the conditions and need for computational thinking, we believe that layering in empathy-eliciting features and supporting collaborative storytelling about the scenario created opportunities for Ollie to recontextualize computational abstractions in ways that enriched both his CT and his moral reasoning. This conjecture stems from our experiences running structurally similar scenarios that included fewer empathy-eliciting features and limited opportunities to flesh out or expand upon the scenario through storytelling. Specifically, we posed a task asking students to fairly distribute a small bucket of Halloween candy among a given number of children. In these sessions, we rarely saw the types of rich reflexivity between CT and fairness reasoning that emerged in Ollie's interview. While children did start to distinguish classes of candy and children (e.g., bigger or better-quality candy held more cachet), they would just as often choose to throw away extra candy so that each child would receive the same number of pieces, or not see the outcome as consequential beyond the intellectual exercise. So, the candy scenario tended to elicit an orientation towards the task aligned with a sense of justice, or equality for all involved (Gilligan et al, 1988). By contrast, we designed the hurricane scenario to tap into children's empathy for others as a productive resource for reclassing through mechanisms like perspective-taking, which can aid in articulating needs, wants, and relationships. Furthermore, the hurricane task and facilitation were designed to support children's extended animation of the problem through co-constructed storytelling, which enables them to recontextualize computational abstractions in details that are consequential *to them*. For Ollie, that involved, for instance, recontextualizing classes of people to include a mother-baby unit engaged in the relational practice of nursing, to layer in practices of resource-sharing, and to draw in people's prior experiences of cold as a tool for sense-making. This reasoning became reminiscent of Gilligan and colleagues' notion of a care voice (Gilligan et al, 1988). We are not saying that storytelling can be a mechanism to tip children from a justice-oriented voice to a care-orientated voice. Rather, the storytelling seemed to function as an interactional mechanism supporting the dialogic between the two discourses in making the judgements about fairness. Ollie and the interviewer socially constructed the "final" moral judgments by coordinating these different perspectives along with Ollie's experiences (Wilgus, 2009).

In our ongoing research, we plan to continue studying this design scenario for other insights as well as draw on these design features to create new scenarios that support rich, integrated CT and fairness reasoning for more students. As we discussed above, the reasoning we see in the interview is shaped by more than just the alignments between Ollie, the interviewer, and the analysis; the clarity with which we see this rich reasoning is partly a function of this linguistic fluency or alignment. The richness of the reasoning and task is also supported by Ollie's willingness to take on the positioning of a decision-maker for the well-being of others, a positioning that may come with/from significant power and privilege. By these arguments, we again highlight the need to continue working with a more diverse student body, task design, and researchers.

5.2. Integrating CT with social-emotional learning in school

Elementary schools have become more invested in supporting students' social-emotional learning (SEL) (Corcoran et al., 2018). SEL includes, among other components, feeling and showing empathy for others, and making responsible and caring decisions (CASEL, 2019). Many have come to recognize that SEL supports a wide range of things, including academic achievement (Durlak et al, 2011; Sklad et al, 2012). While some have attempted to integrate SEL into disciplinary settings, it is most often happening in the arts and humanities (e.g., Omasta et al., 2020), with few in STEM fields taking up opportunities for integration in schools (see Eckert & Butler, 2021, for one recent case). However, some have shown that "coding playgrounds" for children not only teach children programming and CT but also support the development of positive social behaviors such as communication and collaboration (Bers, 2012, 2018). Our work also suggests that it is possible and potentially productive to create opportunities for integrated SEL and STEM learning in ways that enrich *both*. This exploratory research has found that for Ollie, empathy was a resource for seeds of CT; at times, Ollie used CT to manage the emotionally-laden complexity and uncertainty of the decision-making task, for instance, by using conditional logic to invent and reason through many possible futures. These findings suggest that spaces in schools where students are already encouraged to recruit empathy might be a natural place for implementing these kinds of mutually beneficial activities.

6. Conclusion

Seeing computational thinking as a "refinement of everyday thinking" (Einstein, 1936) helps highlight the importance of approaching CT pedagogy in a way that recognizes the full range of children's experiences, including the vital ways that computational practices like abstraction involve emotion, empathy, and perspective-taking. Through this work, we hope to encourage the field to take up more expansive orientations towards CT and to create opportunities for recognizing and nurturing the nascent computational "seeds" in children's everyday reasoning.

Data availability

The data that has been used is confidential.

CRediT authorship contribution statement

Erin Ronayne Sohr: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Ayush Gupta:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Funding acquisition. **Andrew Elby:** Conceptualization, Writing – review & editing, Funding acquisition. **Jennifer Radoff:** Conceptualization, Writing – review & editing, Formal analysis, Funding acquisition.

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