Received: 7 October 2021 | Revised: 2 November 2023 | Accepted: 28 November 2023

DOI: 10.1002/sce.21850

RESEARCH ARTICLE

Science Education WILEY

Why are some students "not into" computational thinking activities embedded within high school science units? Key takeaways from a microethnographic discourse analysis study

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Funding information
National Science Foundation, Grant/Award Numbers: CNS-1138461, CNS-1441041, DRL-1020101, DRL-1640201, DRL-1842374; Spencer Foundation, Grant/Award Number: #201600069

Abstract

Science educators are integrating more and more computational thinking (CT) activities into their curricula. Proponents of CT offer two motivations: familiarizing students with a realistic depiction of the computational nature of modern scientific practices and encouraging more students from underrepresented backgrounds to pursue careers in science, technology, engineering, and mathematics. However, some studies show that increasing exposure to computing may not necessarily translate to the hypothesized gains in participation by female students and students of color. Therefore, paying close attention to students' engagement in computationally intense science activities is important to finding more impactful ways to promote equitable science education. In this paper, we present an in-depth analysis of the interactions among a small, racially diverse group of high school students during a chemistry unit with tightly integrated CT activities. We find a salient interaction between the students' engagement with the CT activities and their social identification with publicly recognizable categories such as "enjoys coding" or "finds computing boring." We show that CT activities in science education can lead to numerous rich interactions that could, if leveraged correctly, allow educators to facilitate more inclusive science classrooms. However, we also show that such opportunities would be missed unless teachers are attentive to them. We discuss the implications of our findings on future work to integrate CT across science curricula and teacher education.

KEYWORDS

chemistry education, computational thinking, equity, microethnographic discourse analysis, social identification, underrepresentation

1 | INTRODUCTION

The past decade in science education has been driven by calls to achieve parity between science education and modern scientific practices (e.g., National Research Council, 2012, 2013). A significant implication of these initiatives is the need to tightly integrate computational thinking (CT) activities across science curricula because modern science increasingly relies on computational tools and methods (e.g., Denning, 2017; Sengupta et al., 2013; Weintrop et al., 2016; Wilensky et al., 2014). However, science who strive to integrate computing into their daily classroom instruction must contend with some of the critical issues surrounding equity and inclusion documented in the prior literature because research shows that computing education environments disproportionately favor White and Asian males while marginalizing female students and students of color (e.g., Kafai et al., 2020; Margolis, 2017; Pinkard, 2005; Scott et al., 2017). As computing is fast becoming a staple of science education, it is important to investigate the nature of students' engagement with CT activities embedded within science units if we are to train competent science teachers and design inclusive science learning environments.

In this paper, we present the results of a microethnographic discourse analysis of interactions among a small racially diverse group of high school students during an 8-day chemistry unit that included tightly integrated CT activities. Our research setting offers three unique affordances in investigating the sociocultural implications of integrating CT across science curricula: (1) the students engaged with computing during a required disciplinary course, not an elective course; (2) they used computing as a tool for making sense of the course content, not as the content of a standalone course; and (3) they engaged with a CT-embedded unit taught by their regular science teacher with their regular classmates in their regular chemistry lab, not from a computer science (CS) teacher in a computer lab. Therefore, our study offers unique insights into students' natural ways of engaging with CT within a science classroom.

In our analysis of student interactions, we focus on the interplay between engagement with CT activities and social identification. We define social identification as the process through which individuals may come to be identified as socially recognized categories of people such as "know-it-all," "good at math," or "not into computers" (Wortham, 2001, 2004). Prior studies show that how students socially identify themselves, as well as how they are socially identified by others, directly impact their content learning in the classroom (e.g., Esmonde, 2009; Handford & Gee, 2013; Honeyford, 2014; Langer-Osuna, 2011; Wortham, 2004). Therefore, it is theoretically plausible that there may be a similar systematic interplay between social identification and engagement with CT activities, and if this is indeed the case, uncovering the nature of this process would provide science educators with unique insights on how to cultivate inclusive science learning environments while integrating CT into their curricula.

Our analytical framework combines Wortham's (2004, 2005) theory of social identification and Bloome et al. (2004) microethnographic discourse analysis approach. By analyzing students' moment-by-moment social interactions while completing the CT activities, we aim to answer the following research questions: *Were there any indicators of the focal group students' social identification with respect to computing when they were engaging with a science unit that included tightly integrated CT activities? If yes, what kinds of interactions led to students' expression and negotiation of their social identities?*

2 | BACKGROUND

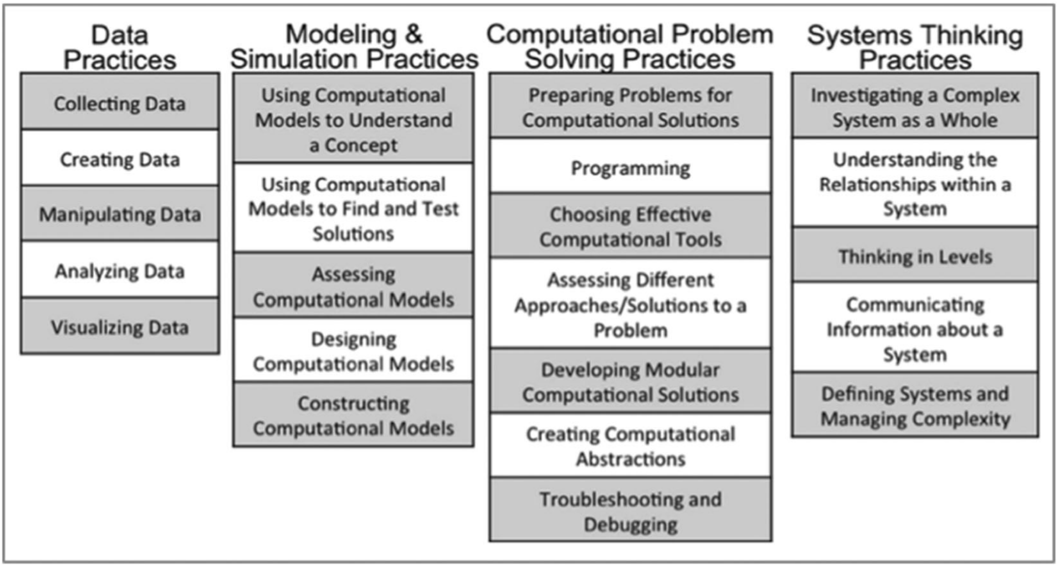
2.1 | Computational thinking in science education

Most efforts to introduce computing in K-12 education invoke the term CT. However, this term remains loosely defined and implies various incompatible conceptual frameworks (Lodi & Martini, 2021). Originally, CT was coined by Papert (1996) to describe students' use of computational representations in constructing and expressing mathematical ideas (see also Papert, 1980). However, CT gained widespread adoption as a standalone term after Wing (2006) revived it to advocate for teaching every student to "think like a computer scientist" (p. 35). This "CS-first" definition was qualitatively different from Papert's ideas because Wing foregrounded teaching kids CS tools and concepts in a domain-agnostic way.

Wing's reframing of CT resonated with then-emerging efforts to promote CS education due to the presumed need for a skilled computing workforce in modern economies. Today, the CS-first framing is commonly adopted by studies and initiatives on promoting pre-college standalone CS education (e.g., Barr & Stephenson, 2011; Brennan & Resnick, 2012; Code.org, 2022; K-12 Computer Science Framework Steering Committee, 2016; Vogel et al., 2017; Wilson, 2014). However, Wing's framework draws criticism for two shortcomings. First, it foregrounds a software-development-centric view at the expense of other rich forms of computing used in domains such as biology, sociology, art, and music (Wilensky et al., 2014). Second, standalone CS courses risk disadvantaging female students and students of color whose participation in elective CS courses is lower than those of White and Asian male students (e.g., Sax et al., 2020; Wyatt et al., 2020).

Wilensky et al. (2014) argued that a complementary approach to overcome the shortcomings of the CS-first framework would be to tightly integrate computing into science curricula. Building on earlier work of Papert (1980; 1996) and diSessa (2000), they advocated for teaching computing as a literacy that uplifts students' access to powerful ideas and knowledge construction in all science, technology, engineering, and mathematics (STEM) domains. Wilensky et al. argued that integrating CT into STEM curricula would yield four benefits for all students: (1) increasing access to computing, (2) increasing motivation toward learning science, (3) introducing authentic scientific practices of the 21st century, and (4) teaching how to use computing to make sense of their worlds instead of isolated coding activities like sorting, recursion, and so on.

Wilensky et al.'s (2014) "literacy-first" framework, which is also commonly referred to as the CT-STEM framework, gained widespread adoption in the last decade and inspired many studies on integrating CT across science curricula (e.g., Grover & Pea, 2018; Lee et al., 2020; Philip & Sengupta, 2021; Weintrop et al., 2016; Wilensky, 2003). Subsequently, Weintrop et al. (2016) interviewed scientists and mathematicians who use computing in their day-to-day work and operationalized CT-STEM as a taxonomy of computational practices in four categories: data analysis, computational problem-solving, modeling and simulation, and systems thinking (Figure 1). In recent years, the CT-STEM taxonomy has been widely used as a design framework to support curricula created with tightly integrated CT activities (e.g., Guo et al., 2016; Thompson et al., 2020) and teacher training programs



Data Practices	Modeling & Simulation Practices	Computational Problem Solving Practices	Systems Thinking Practices
Collecting Data	Using Computational Models to Understand a Concept	Preparing Problems for Computational Solutions	Investigating a Complex System as a Whole
Creating Data	Using Computational Models to Find and Test Solutions	Programming	Understanding the Relationships within a System
Manipulating Data	Assessing Computational Models	Choosing Effective Computational Tools	Thinking in Levels
Analyzing Data	Designing Computational Models	Assessing Different Approaches/Solutions to a Problem	Communicating Information about a System
Visualizing Data	Constructing Computational Models	Developing Modular Computational Solutions	Defining Systems and Managing Complexity
		Creating Computational Abstractions	
		Troubleshooting and Debugging	

FIGURE 1 Computational thinking in science and mathematics (CT-STEM) taxonomy. *Source*: Weintrop et al. (2016).

(e.g., Kelter et al., 2021; Peel et al., 2020). Recent studies show that science units designed according to the CT-STEM taxonomy can improve students' CT skills and science content learning (e.g., Guo et al., 2016; Arastoopour Irgens et al., 2020; Swanson et al., 2018).

However, despite the rapidly increasing popularity of CT integration across K-12 education through both the CS-first and CT-STEM frameworks, some researchers recently voiced concerns about the lack of research on the sociocultural implications of CT (e.g., Kafai et al., 2020; Kafai & Proctor, 2021; Rodriguez & Lehman, 2017; Vakil, 2018). For example, Kafai et al. (2020) argued that most studies on CT focused on knowledge and skill acquisition instead of framing computing as a literacy, which requires adopting a broader societal view of computing by incorporating factors such as students' values, biases, identity positions, cultural practices, contemporary concerns, and lived experiences. Similarly, Vakil (2018) argued that calls to promote CT often cited equity-oriented concerns but failed to articulate the political and societal implications of their advocacy. In this study, we aim to address the gap in CT-STEM research articulated by Kafai et al. (2020) and Vakil (2018) by focusing on social identification as a potentially fruitful mechanism that can elicit insights into the sociocultural implications of CT integration.

2.2 | The implications of underrepresentation in computing for science education

In U.S. high schools, CS is taught as a standalone course separate from the science courses (e.g., biology, chemistry, environmental science, physics). Therefore, the title of this subsection may seem unusual at first because many readers may assume that only CS educators need to worry about the persistent underrepresentation of women and Black, Indigenous, and People of Color (shortly BIPOC) in computing education and the professional computing workforce (e.g., Google LLC & Gallup, Inc, 2020; National Center for Science and Engineering Statistics [NCSES], 2023; US Department of Labor, Bureau of Labor Statistics USBLS, 2022). However, there is a nontrivial chance that issues stemming from computing may soon spill over to science classrooms because CT is becoming a core component of STEM education. In this subsection, we briefly review the literature on representational disparities in computing to highlight the potential implications of these issues on integrating CT into science curricula.

Women and BIPOC are significantly underrepresented in computing at all levels. Only about a quarter of employees in computing-related fields are women in the United States; even fewer are BIPOC (Martin et al., 2015; US Department of Labor, Bureau of Labor Statistics USBLS, 2022). The number of male authors publishing articles in CS journals dwarfs those of female authors (approximately 4-to-1, according to Wang et al., 2021). Approximately four out of five CS bachelor's degrees are awarded to men (McAlear et al., 2018; NCSES, 2023). A total of 76% of the students taking the Advanced Placement (AP) CS courses in the United States are male, and 78% are White or Asian (Wyatt et al., 2020). Women of color are the least represented group across all levels. They make up approximately 20% of the U.S. population, yet less than 10% of the CS professionals, bachelor's degree earners, and AP course takers (McAlear et al., 2018).

Such disparities highlight an underlying negative feedback loop starting from early computing education opportunities, intensifying in higher education, and crystallizing in professional settings. On the one hand, people often perceive computing as a primarily White or Asian male endeavor that encapsulates many adverse sociocultural implications for everyone else (Google LLC & Gallup, Inc., 2016, 2020; Wang & Moghadam, 2017). On the other hand, the association between White male identity and computing can make it an undesirable pursuit for female students and students of color (Corneliussen & Prøitz, 2016; McAlear et al., 2018). This feedback loop causes the underrepresentation issue to persist through generations, and recent statistical data shows a steady trend with no improvement in achieving equitable participation in computing (NCSES, 2023; Pew Research Center, 2021).

Furthermore, the formal and disconnected nature of standalone CS courses might overlook students' diverse and social ways of learning and knowing (Turkle & Papert, 1992). Female and BIPOC students report lower interest in CS because they see it as a discipline for male students from dominant communities (Gal-Ezer et al., 2009; Master et al., 2016; Scott et al., 2017). Some students also report that they prefer group work and collaboration, dislike sitting in front of a computer for extended time periods, and wish to pursue more people-oriented domains (Carter, 2006; DuBow & Pruitt, 2019). They see computing as antisocial and inattentive to communal goals (Diekman et al., 2010; Yardi & Bruckman, 2007). Those who take CS courses report unpleasant experiences, such as male students dominating group discussions and ignoring others' suggestions (Butler, 2000; DuBow & Pruitt, 2019; Silverman & Pritchard, 1993).

Many contemporary initiatives implicitly assume that simply increasing female and BIPOC students' exposure to computing would be sufficient. However, recent studies suggest that more exposure does not automatically result in increased enjoyment of computing or motivation to learn more about computing (Ashcraft et al., 2017; Lang et al., 2015; Scott et al., 2017). Short-term interventions and specialized programs fail to increase female and BIPOC students' participation in computing (e.g., Sax et al., 2020; Scott et al., 2017; Wyatt et al., 2020). For example, a study by Sax et al. (2020) concludes that the AP CS Principles (CSP) course, which was explicitly designed to increase diversity (see Wyatt et al., 2020), fails to broaden participation because it fails to attract meaningfully diverse cohorts and the students who take the CSP course report much lower interest in pursuing computing careers.

Our brief review here shows that integrating CT across science requires deliberate designs and interventions to prevent disadvantaging students from underrepresented backgrounds. We argue that uncovering how students come to see themselves and others as they are learning science with CT activities can help improve the design of educational technologies, curricular units, and teacher training programmes. Thus, we focus on a possible interaction between social identification and engagement with CT activities.

2.3 | Social identification

Social identification is the process through which individuals and groups become associated with publicly recognized categories of people, such as being "a dog person," "a harsh teacher," or a "math geek" (Bloome et al., 2004; Cian et al., 2022; Wortham, 2001, 2004). Research shows that thinking of oneself as "good" or "bad" in a domain is a salient aspect of identity, and the development of such an identity, in turn, influences how much a student learns in the classroom (Ireland et al., 2018; Wieselmann et al., 2020; Wortham, 2004). Analyzing social identification offers opportunities to understand the interplay between students' social identities and the emergence of classroom-level differences in participation and learning outcomes. More importantly, social identification offers insights into the threads of continuity between macro-level societal issues and micro-level events that happen as part of daily classroom life (Bloome et al., 2004).

Bloome et al. (2004) argue that classrooms are complex places where “teachers and students create and re-create, adopt and adapt, and engage in a full range of human interactions” (p. xvi), which means that teaching literacy is as much a matter of “language socialization, enculturation, identity production, power relations, and situated interaction” (p. xvii) as teaching how to manipulate symbol systems. Therefore, analyzing this complex process requires attending to cues and signals from multiple levels of phenomena, such as social–historical patterns that develop over decades or centuries, ontogenetic patterns that develop over one's upbringing, local patterns that develop over days or weeks, and microgenetic patterns that develop over the course of short-term interactions (Wortham, 2004).

In this study, we focus on understanding the microgenetic patterns in our data because we aim to find out whether integrating CT into science curricula would compel students to signal their social identities with respect to CT as they are learning CT. Accordingly, we use Bloome et al.'s (2004) microethnographic discourse analysis method, which describes how to systematically dissect classroom interactions by identifying verbal and nonverbal cues, event boundaries, thematic elements, and broader contextual settings within the worlds in which students and teachers live. In the following section, we describe our study methodology and our use of the analytical and theoretical tools developed by Bloome et al. in greater detail.

3 | METHODOLOGY

3.1 | Research setting

This study emerged during a preliminary analysis of the data we collected for an earlier study on high school students' chemistry learning with tightly integrated CT activities (henceforth referred to as “the original study”; Aslan et al., 2020). The original study consisted of two phases. First, we collaborated with two in-service chemistry teachers from a public high school in the US Midwest to design a curricular unit about ideal gas laws that was uniquely tied to integrated CT activities. Then, the teachers taught the unit during a 2-week implementation with more than a hundred participating students. The original study did not include instruments to collect data on social identification or other relevant sociocultural implications of CT. However, during a preliminary analysis of our video data, we noticed student interactions that were rich in social interaction and decided to formulate the research questions of this study.

3.2 | Curriculum summary

The Connected Chemistry 2 Unit (pseudonym, shortly CC2) is a new, modern chemistry unit on ideal gas laws with six lessons (Table 1). Each lesson contains at least one tightly integrated CT activity designed according to the CT-STEM taxonomy by Weintrop et al. (2016). The CT activities include computational modeling, programming, simulation-based experiments, and computational data analysis tools. The unit also includes physical hands-on lab experiments, conceptual inquiry activities, small group discussions, and teacher-led whole-class discussions. These experiences aim to mimic a modern scientific inquiry process where the students first infer the kinetic molecular theory conceptually and then derive the ideal gas equation ($PV = nRT$) themselves. The CT activities in this unit serve the same functions CT would serve in a modern research lab, albeit in a simplified and scaffolded manner. They facilitate constructing computational models of real-world phenomena, analyzing data generated from real-world observations and computational models, testing hypotheses with lab experiments and computational models, and systematically examining the insights gained from these processes to develop theories that can plausibly explain real-world phenomena.

TABLE 1 An overview of the CC2 unit.

Lesson	Title	Duration	Learning objectives	Example CT activity
1	Introduction	2 periods (80 min)	Cultivating students' naive theories about the particulate nature of matter and KMT.	Using a simplified coding environment to create a computational model of an air duster as a fixed-volume container with gas particles inside.
2	What is pressure?	2 periods (80 min)	Learning the assumptions of KMT. Learning how micro-level interactions among gas particles lead to the emergence of pressure as a macro-level phenomenon if they behave as described by KMT.	Conducting computational experiments with a predeveloped bike tire model to understand what happens when we pump air into a bike tire (i.e., increasing the number of particles).
3	Pressure—Number	1 period (40 min)	Understanding the quantitative relationship between the number of particles in a container and gas pressure. Developing a mathematical model to estimate this relationship (i.e., Avagadro's Law).	Learning how to automate computational experiments to collect repeated measures data for the number of particles (n) and gas pressure (P) variables, and then using an integrated data analysis tool to estimate the mathematical relationship between the two parameters.
4	Pressure—Temperature	1 period (40 min)	Understanding the relationship between the gas temperature in a container and gas pressure. Developing a mathematical model to estimate this relationship (i.e., Charles' Law).	Conducting automated computational experiments with a predeveloped model that allows changing the temperature parameter (T) by heating and cooling the walls of a gas container, and then using a data analysis tool to estimate the mathematical relationship between the two parameters.
5	Pressure—Volume	1 period (40 min)	Understanding the relationship between the container volume and gas pressure. Developing a mathematical model to estimate this relationship (i.e., Boyle's Law).	Conducting automated computational experiments with a predeveloped *virtual syringe* model that allows moving the plunger to change the volume (V), and then using a data analysis tool to estimate a nonlinear equation that explains the relationship between volume and pressure.
6	The ideal gas equation	1 period (40 min)	Combining the three estimated equations from the previous explorations to derive the ideal gas equation.	N/A

Abbreviation: KMT, Kinetic Molecular Theory.

A detailed review of the entire CC2 unit is beyond the scope of this paper. However, we provide a summary of the introductory lesson below to illustrate how we incorporated CT practices with chemistry content. The entire unit and the accompanying teacher guide are published online as open-source materials and will be included in the online version of this paper as Supplementary Materials. We also published empirical results indicating positive outcomes in students' chemistry content learning and CT skills after engaging with the CC2 unit elsewhere (Aslan et al., 2020).

3.2.1 | Example learning sequence: Constructing a computational model of gas pressure inside an air duster

The first activity of the CC2 unit is an open-ended exploration of an air duster canister (also called compressed air or canned air), which is an everyday object that can be bought in a store to clean dust from sensitive equipment such as computer keyboards or hard-to-clean surfaces such as air vents. Students analyze an air duster because it has a fixed volume and only requires gas particles to function, so it is simple to scrutinize. The unit imagines students to have access to real air dusters in the lab. However, we also provide a video to students that demonstrates a simple experiment where pressing the valve of a full air duster scatters a pile of confetti paper on a desk, but an empty one does not.

After tinkering with physical air dusters and watching the video demo, students write their hypotheses on what happens when the valve of an air duster is pressed. Then, they illustrate their hypotheses by hand-drawing sketch models (Figure 2). Once students complete their sketch models, their teacher conducts a whole-class discussion by asking some students to explain the ideas in their drawings. The unit asks teachers not to explain which ideas were correct but only attempt to make their students aware of the diversity of their classmates' ideas on how air dusters work.

Finally, students convert their hand-drawn models into computational models through scaffolded activities. First, they create a static model by placing computational objects such as particles, stationary walls, and removable gates in a two-dimensional view. Then, they use a simple blocks-based coding environment to define how the particles behave (Figure 3). This programming environment is created with the NetLogo agent-based modeling environment (Wilensky, 1999) and its NetTangoWeb blocks-based programming interface (Horn et al., 2020). This activity allows students to test their hypotheses by seeing if their model would produce the desired outcome of particles spraying out of the container. At the end of the lesson, students conduct small group discussions to compare each other's computational models and write their reflections.

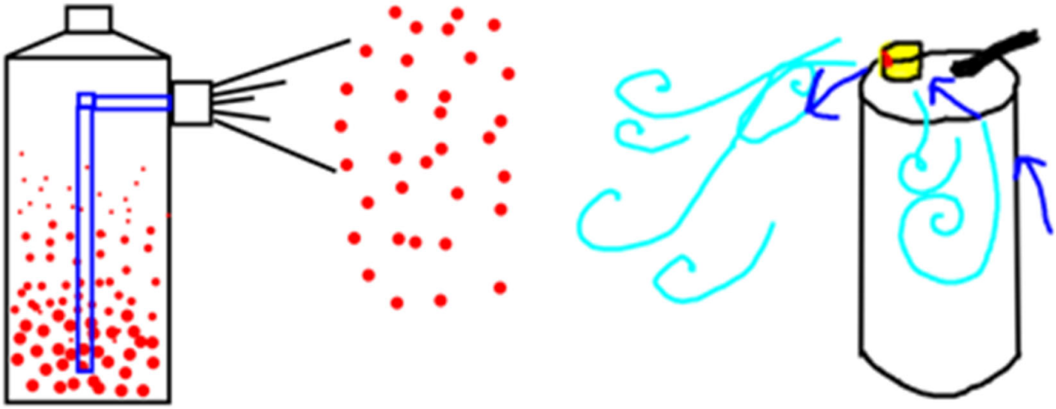


FIGURE 2 Examples from students' hand-drawn sketches.

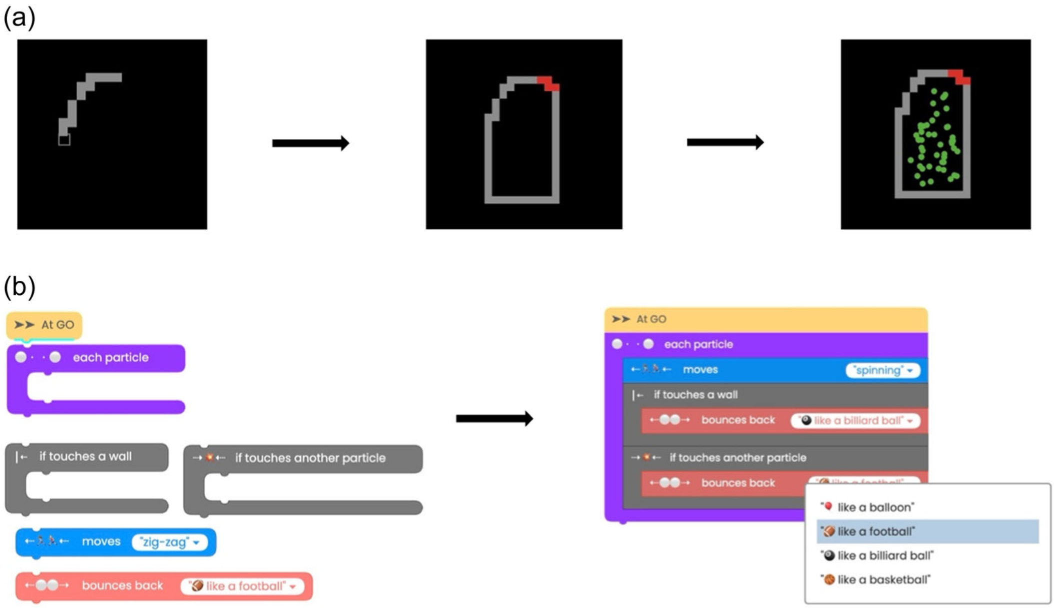


FIGURE 3 An example screenshots from the computational modeling activity in the first lesson: (a) using a static modeling toolkit to construct a gas container by placing walls and particles, (b) using a blocks-based programming environment to define how the particles move, interact with the container, and interact with each other.

3.3 | Data sources

As mentioned above, we extracted the data set of this study from the original study through preliminary reviews and data reduction. In the original study, two participating teachers taught the CC2 unit in seven periods, and more than a hundred of their students consented to data collection. Both teachers asked students to form small groups to work on the unit collaboratively because that was how they taught the previous chemistry units during the school year. If every student within a group consented to audiovisual data collection, we placed a small video camera on their lab desk and recorded their interactions. The first author was present during the implementation as a participant observer. The data set of the original study included video recordings from five focal groups. However, we decided to choose only one of them as the focal group of this study so that we could conduct a robust, in-depth analysis of their interactions. In addition, the students accessed the unit through an online learning management system (LMS) and posted their work (e.g., textual answers, hand-drawn sketches, code blocks, screenshots, and spreadsheets) on this LMS. Therefore, the data set of this study consists of approximately 320 min of video data and more than 100 short responses submitted by each participating student on the LMS.

3.4 | Participants

The focal group of our study consists of three students who completed the activities as a group during the entire unit, whose pseudonyms are Grant (White male), Ray (Black female), and Seven (White male). We chose them as our focal group for this study for two reasons. First, the demographic composition of their group was conducive to answering our research questions. Second, there were sufficient indicators that they did not alter their daily classroom practices during data collection despite being video recorded. They completed the activities as their teacher instructed, but at the same time, regularly conversed about the subject matter, the computational activities, and even out-of-class matters. In addition, their teacher, Ms. Bee (pseudonym), occasionally asked multiple groups to merge for discussion activities. These expanded group discussions provided us with additional rich interactions to analyze.

Table 2 shows the list of all study participants who appeared in the recordings of our focal group and, hence, were subjects of our analysis (see Figure 4 for seating arrangement charts). Table 2 also includes the demographic

TABLE 2 Demographics of the study participants.

Pseudonym	Race (self-reported)	Gender (self-reported)	Participation
Grant	White	Male	Focal group
Ray	Black	Female	Focal group
Seven	White	Male	Focal group
Ava	Black	Female	Temporary interactions with the focal group
Elly	White	Female	Temporary interactions with the focal group
Moss	White	Male	Temporary interactions with the focal group
Ms. Bee	Afro-Caribbean	Female	Teacher
Mr. A	White	Male	Researcher/participant observer

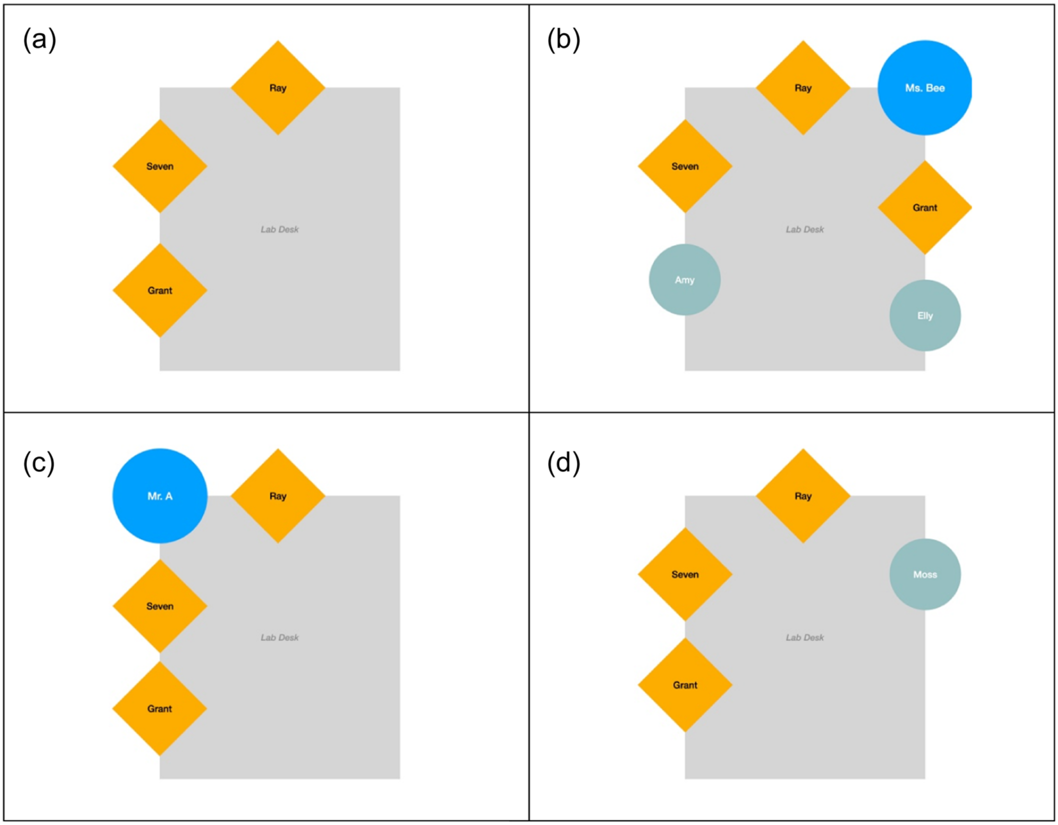


FIGURE 4 Seating arrangements during the classroom computational literacy events during (a) Transcript 1, (b) Transcript 2.2, (c) Transcript 3, and (d) Transcript 4.

backgrounds of their teacher, Ms. Bee, and the participant observer, Mr. A (pseudonym for the first author), in the table because our data set consists of interactions between them and the students.

3.5 | Data analysis

Following Bloome et al. (2004), we employed the microethnographic discourse analysis method to analyze our data and answer our research questions. This method provided us with a systematic approach to parse complex social interactions into meaningful units of analysis at multiple levels of granularity and determine signaled social identities based on participants' verbal remarks and nonverbal behavior. As Bloome et al.'s research is situated in language and literacy education, we made necessary adjustments to some of their methodological constructs to better suit our data and research questions.

Our primary adjustment to Bloome et al.'s methodological constructs was to define our unit of analysis as a classroom computational literacy event (CCLE). We derived this construct from Bloome et al. (2004), who define their unit of analysis as a classroom literacy event, which encompasses any bounded social event where written language plays a significant role. We made this adjustment because we assume that learning, knowing, and thinking with computing are sufficiently different than doing so with traditional literacies (diSessa, 2000; Kafai et al., 2020; Wilensky et al., 2014). Thus, we defined a CCLE as a bounded social event where engagement with CT plays a nontrivial role. We marked an event as a CCLE only if it includes a social interaction prompted by a meaningful engagement with a computational activity during the natural progression of students' science learning experience in the classroom (e.g., completing activities, making sense of ideas, constructing knowledge). Narrowing our focus to CCLEs ensured that our analysis only included events relevant to our research questions.

Before starting our microethnographic analysis, we conducted a preliminary open-ended review of our video data. We watched the entire video data set and marked interactions that included all the components of a CCLE. This initial data reduction process yielded 10 candidate CCLEs. We extracted these CCLEs as standalone video clips and transcribed them verbatim. We also extracted the students' submissions on the LMS for each CCLE.

We conducted our microethnographic analysis in three stages. In the first stage, we parsed and enhanced our verbatim transcripts using the following four constructs from Bloome et al.:

- Contextualization cues: linguistic forms that contribute to signaling contextual presuppositions (e.g., pausing, stress patterns, intonation, changes in volume, speed of delivery, and stylistic changes; see Table 3).
- Message units: smallest units of conversational meaning identified through participants' use of contextualization cues.
- Interactional units: series of conversationally tied message units.
- Thematic coherence: organization of meanings within and through a CCLE to answer the questions “What is this interaction about?” and “What are the participants talking about?”

We determined the contextualization cues in each utterance by carefully watching the video data multiple times and paying attention to students' nonverbal behavior (e.g., posture, gaze, intonation) as much as their verbal remarks. We embedded some contextualization cues (e.g., intonation, pausing, interruption) within the transcripts using the symbols in Table 3. We also created a new column titled “non-verbal behavior” to label participant actions such as turning toward someone, pointing at something, etc. Then, we used the contextualization cues to divide each transcript into message units. Third, we grouped interrelated message units within interactional units. Finally, we determined the theme in every interactional unit and compared them within and across CCLEs to track thematic coherence.

TABLE 3 Symbols used to indicate nonverbal contextualization cues in the transcripts.

Symbol	Description
ʅ	Short pause (≈0.5 s)
ʅʅ	Medium pause (≈1 s)
ʅʅʅ	Long pause (more than 1 s)
┌ └	Overlapping talk
┐ └	Interruption
==	Unfinished sentence or utterance
+	Elongated vowel
*… *	Change in pitch or speaking style, emphasis, or loud talk
°… °	Low pitch or whispering
↑	Rising intonation at the end of the sentence
⍰ ⍰ ⍰ ⍰	Undecipherable utterance
(…)	Nonverbal behavior or transcriber comments for clarification

In the second stage of our microethnographic analysis, we added a new "signaled identities" column to our transcript tables. We populated this column by closely examining each message unit based on Wortham's (2004) operational definition of the components of social identification. For example, we paid close attention to the following indicators: verbal remarks or nonverbal behavior indicating belonging to (or exclusion from) a social category, expressions of enjoyment or enthusiasm (or lack thereof), social positioning moves, and reactions to others' social identification (e.g., validating, ignoring, contesting). In addition, we contextualized each message unit based on the theme of the ongoing interactional unit, the thematic connections with previous interactional units, and our familiarity with the local implementation context. Finally, we reviewed the data from the LMS that students used to access unit contents (e.g., video demos, CT activities, lab experiment instructions, datasheets) and post their work for Ms. Bee to review (e.g., textual answers, sketches, data sheets) to gain more insights into students' learning experiences and to triangulate our interpretation of their verbal remarks and nonverbal behavior.

4 | FINDINGS

In this section, we present three key findings using a chronological structure. First, we show that engaging with the CT activities in the CC2 unit prompted social identification, and our focal group quickly established a binary distinction between those who were into computers and those who were not. Then, we show that social identification influenced the students' engagement with the unit's content. Finally, we show that engaging with computing in a chemistry learning context offered glimpses of nonstereotypical depictions of computing that problematized the binary social categories established by our focal group. Following Bloome et al. (2004), we utilize thick descriptions of each CCLE because analyzing social identification requires paying close attention to subtle indicators in social events, and every assertion about a student's social identity or the nature of their social identification requires us to provide substantial evidence to qualify as sound evidence.

4.1 | Encountering CT activities in a chemistry unit prompted spontaneous interactions that signaled the focal group students' social identities

The first interaction with observable elements of social identification happened when the students encountered the very first CT activity of the unit. Until then, they completed noncomputational activities. Although Ms. Bee told them this unit was designed in collaboration with a research team, she did not depict it as a computing-centric unit. Thus, the interaction in Transcript 1 happened when the students encountered concepts such as computational modeling and programming for the first time in the unit.

Transcript 1

Lesson 1, Day 1

1	RAY	⌈ This video is confusing me
2	GRANT	⌊ I'm on this page (sighs) ⍰ ⍰ ⍰ ⍰
3	RAY	How do we know this?
4		⎱ *Oh, so we have to code+ in like actuality?*
5		⎱ I don't know how to code. ↑
6		I don't even know how to block code.
7		When we were in middle school, we did this stuff.
8		⌈ Everybody else did it for me.
9	GRANT	⌊ Remember the hour of code?
10	RAY	Yeah
11	SEVEN	I know code. *(smiles)*
12	GRANT	That was fun.

Ray's remarks in the beginning, and the change in her intonation, indicate that she did not expect a computational activity in this chemistry unit (Lines 3 and 4). Perhaps due to this surprise, she told her friends that she did not know coding and clarified that she did not "even know how to block code" (Lines 5 and 6). We interpret Ray's remarks as an indication of her deliberately distancing herself from coding and emphasizing to others that her negative remarks about coding were not just due to the perceived difficulty of coding because blocks-based programming is a popular visual modality that is often considered more novice-friendly than text-based programming (e.g., Bau et al., 2017; Weintrop & Wilensky, 2015). Her remarks on how she avoided doing a coding activity at middle school (Lines 7 and 8) support this interpretation. Therefore, we argue that Ray signaled her social identity to her peers as someone who does not know how to code and is not enthusiastic about learning it.

Seven and Grant's reactions exhibited indicators of social identification, as well. Grant interrupted Ray and asked if the others remembered the Hour of Code (Line 9), a popular short-term standalone workshop offered by a nonprofit (see Code.org, 2022). On one hand, he probably asked this question because Ray was reflecting on her own middle school programming experience. On the other hand, he completely ignored Ray's apathetic tone and expressed positive sentiment toward the Hour of Code workshops (Line 12). Seven stated that he knew code, but he also smiled while saying it (Line 11), which indicated that he had an affinity for coding. Therefore, we interpreted the male students' remarks as acknowledging Ray's social identity as someone who is not enthusiastic about coding and positioning themselves in an opposite social category of students who know and like coding.

4.2 | There was a salient interplay between social identification and learning chemistry with CT

Our analysis showed that students relied on clues from others' social identification when interpreting their engagement with the unit (e.g., success, knowledge, confidence). We present two successive interactions from the 3rd day of the implementation to illustrate this finding. Both interactions happened after students were provided a static modeling toolkit that allowed them to recreate their hand-drawn sketches with computational building blocks: they could add static walls, removable walls, and particles with different colors to their models. This static modeling activity required students to engage with the "creating computational abstractions" practice from the CT-STEM taxonomy. After this activity, Ms. Bee asked two other students, Elly (White, female) and Ava (Black, female), to join Ray, Seven, and Grant to discuss the computational sandbox tool. The prompt on the LMS was as follows: "The sandbox model you just used is obviously very limited. It only has a small number of tools. If you were to extend it, what would you add? What kind of options would you give to the users? Why?" The first interaction in Transcript 2.1 happened at the beginning of this discussion activity.

Transcript 2.1

Lesson 1, Day 2

13	ELLY	⍰ ⍰ ⍰ ⍰ get it to like actually upload+
14	RAY	Oh. I didn't have any problems ⌉
15	SEVEN	⌊ Just not enough tools ⎱ ⎱ *(shakes head)*
16		and the particle
17		You can't see the particles
18		If you put like squares and like
19		If there==
20		If the object is filled with squares
21		you can't see the particles in it
22		It doesn't like ⎱ ⌈ doesn't go. It doesn't overlap+.
23	ELLY	⌊ Oh yeah+ there is not like differentiation ⍰ ⍰ ⍰ ⍰
24	SEVEN	It just like ⎱ ⎱ it's just a whole different surface
25	RAY	Oh+
26		⎱ I didn't have any problems+
27		*But I'm not like a computer person either*
28		So that's probably why my opinion was
29		"It's cool" (impersonating inner speech)
30		"There were enough tools" *(smiles)*

As her remarks in Line 13 show, Elly initiated the discussion with negative remarks about a file-uploading widget on the LMS, which was not a part of the sandbox activity. She used the term "upload," which may have indicated her familiarity with computing terms. Seven, on the other hand, displayed confidence in his grasp of the modeling toolkit by arguing that the modeling toolkit did not have enough tools (Lines 15–24), which prevented him from achieving his goals. He also interrupted Ray's attempt to respond at Line 14 and ignored Elly's initial comments, which indicated that he was probably oblivious to their answers. Elly affirmed Seven's arguments (Line 23), which indirectly signaled her acceptance of his social identity as a student who knew computing and did not like this modeling sandbox activity.

Ray stated an opposite opinion to Elly and Seven, which positioned her in the opposite social category (Lines 25–30). She said she had no problems with the sandbox and even smiled at one point (Line 30). However, she also cautioned that she was “not a computer person” (Line 27) and that her perceived success with the sandbox activity might have been due to her being different from Seven and Elly. In other words, Ray implied that Elly's and Seven's social identities were a factor when she evaluated their negative comments against her success with the CT activity.

Just when Ray finished her remarks, Ms. Bee approached the group. She asked, “Ray, are you talking about the activity?” implying that she suspected the group was chatting about irrelevant topics. Then, she approached the group and probed them about the unit's content. In Transcript 2.2, we present our detailed microethnographic discourse analysis of the group's interaction with Ms. Bee. We also present a detailed table of the nonverbal behavior, and our interpretation of the social identities signaled in the message units.

Transcript 2.2

Lesson 1, Day 2

Line	Speaker	Message Unit	Interaction	Non-verbal behavior	Identities Signaled in the Message Unit
31	MS BEE	So, what's this discussion about over here?	1	Ms. Bee stands between Ray & Grant, looks towards Seven.	
32	AMY	We are talking ⌈ about the sandbox model =	↓		
33	RAY	⌊ The sandbox activity	↓		
34	MS BEE	Ok. What about it?	↓		
35	RAY	Well ⌈ they feel like	↓	Ray looks at her computer, doesn't turn to Ms. Bee.	Ray positions herself as an outsider. Ray positions Elly and Seven as the insiders.
36	SEVEN	⌊ It's buggy.	↓	Seven looks at his computer, speaks while Ray's speaking.	Seven claims the social identity of a knowledgeable person.
37	RAY	They should add + and stuff	↓	Amy & Seven look at Ray.	Ray positions the creators of the computational tool as a separate social category or group.
38	AMY	And we == ⌉	↓	Amy points at Ray.	Amy attempts to claim the social identity of an outsider.
39	RAY	⌊*But* I said that I feel like they shouldn't add anything	↓		Ray reiterates her claim of being an outsider, while ignoring Amy's attempt to join her.
40		like I had the perfect amount of tools	↓		
41		but like I'm not into computers and stuff like that	↓		Ray claims the social identity of a person who is disinterested in computing.
42		So, I feel like somebody who does this stuff would know the difference	↓	Ray shrugs gently twice by moving her shoulders up and down.	Ray claims the social identity of a person who is not knowledgeable in computing.
43		But for me ⎱ I guess it was enough	↓		
44		I made the model	↓		Ray claims the identity of a successful student in this unit.
45	MS BEE	What do you say because you are into computers	2	Ms. Bee turns towards Grant, pointing at him with her index finger.	Ms. Bee upholds Ray's social identification as disinterested and unknowledgeable in computers.

(Continues)

Line	Speaker	Message Unit	Interaction	Non-verbal behavior	Identities Signaled in the Message Unit
					Ms. Bee socially identifies GRANT as interested and knowledgeable in computers.
46		That's what she said	↓	Ms. Bee points back towards Ray with her thumb.	Ms. Bee indicates that she takes Ray's social identification of herself and the others at face value.
47	GRANT	⎰⎰ I also	↓	Grant looks down, leans forward, and touches the desk. Pauses for a while. Then, puts his hands in his pockets	
48		I just ⎰	↓		
49		a bunch of people agree that	↓	Grant looks at his computer screen, scrolls the mouse, indicating that he is reading a text.	Grant takes on the role of the speaker of the group. Grey positions Seven and Elly as knowledgeable.
50		Umm ⎰	↓		
51		There is not enough like tools in the in thing ⌈ because	↓		Grant accepts the social identity of interested computers.
52	MS BEE	⌊ Like what kind of tools?	↓	Ms. Bee briefly glances at Grant's computer.	
53	GRANT	It was just like ⎰ ⎰ ⎰	↓		
54		There is an issue with like ⎰ ⎰ uploading like files ⎰ stuff like that for like for the toolkit ⎰ and yeah	↓		
55	MS BEE	So, what would you add?	3	Ms. Bee turns from looking at Grant to looking at his computer.	
56	GRANT	umm ⌉	↓		
57	SEVEN	⌊ Other shapes	↓	Seven is typing. He keeps looking at his computer and typing while speaking.	Seven claims the social identity of being an insider, authoritative and interested in computers.
58	GRANT	Yeah, maybe a shape because like== ⌉	↓		
59	MS BEE	⌊ Shapes for the+ containers?	↓	Ms. Bee looks at Seven.	Ms. Bee accepts Seven's social identity.
60	GRANT	Yeah	↓		
61	SEVEN	um-hum	↓	Seven hums to indicate that he agrees with Grant's answer.	

Ray repeated her remarks from Transcript 2.1 and told Ms. Bee that she had no issues with the activity because she was "not into computers" (Lines 39–44). Her expression of these ideas in the presence of Ms. Bee showed that she thought the existing social categories and her social identification were not unusual. She also used the pronoun "they" (Lines 35 and 37) to explicitly demarcate herself from the others in the group. Finally, she ignored Ava's attempt to join her (Line 38), probably because she wanted to finish her thoughts as others often interrupted her, interrupted her (e.g., Line 36).

It was notable how readily Ms. Bee accepted the existence of the two social categories that were made explicit by Ray's comments. She upheld the social categories that developed before her involvement with this group, and actively used Ray's exact words to position Grant as "into computers" (Line 45), even adding "that is what she said" (Line 46) even though Ray did not explicitly name any of her peers or make any gestures toward any of them. Ms. Bee spontaneously considered Grant, a White male student, to fit in this social category but not Ava or Elly.

Grant responded to Ms. Bee's characterization affirmatively, although it was clear that he was not comfortable answering her questions. In a way, his social identification was the exact opposite of Ray's. He was not doing well, but being a member of the "into computers" social category gave him the confidence to assume the role of a spokesperson for the group. He presented Seven's remarks as the group's consensus (Line 49) and ignored Ray's critical remarks. The substance of his answer and the nonverbal indicators showed that Grant was not confident in his knowledge. He repeated Seven's and Elly's comments. By doing so, he confirmed Elly's and Seven's social identities as into computers and excluded Ray and Ava from this social category. When confronted with a follow-up question, he faltered only to be helped by Seven.

Seven showed extreme confidence once again and claimed the identity of a knowledgeable person in computing throughout the interaction. Although Ms. Bee never asked him a question directly, he interrupted his peers' answers twice, once to implicitly claim the pronoun "they" used by Ray (Line 36) and once to help Grant answer a difficult follow-up question (Line 57). His nonverbal behavior exhibited confidence, too. He never directly looked at Ms. Bee or others while they were speaking. Although he kept looking at his computer and typing some text, he constantly intervened with short remarks (e.g., Lines 36, 57, 61). He claimed the social identity of a person who is into computing and knows computing well.

Elly opened the discussion in this CCLE, but Ray and Seven quickly sidelined her. Ray interrupted Elly at Line 33 and did not allow Ava to interrupt her at Line 38. Ava did not participate in this interaction at all. Based on Ray's and Grant's nonverbal behavior, we hypothesized that our focal group students socially identified Elly as into computers and Ava as not.

Comparing their coursework uploaded on the LMS (Table 4), we noticed that Ray and Elly did much better than the other three students in these open-ended activities. More importantly, Ray did as well as her peers in terms of using the modeling sandbox and displaying a good understanding of the chemistry content. For example, only Ray mentioned fast-moving air molecules and the term pressure in her response. Elly's computational model was slightly more accurate because it included numerous particles evenly distributed inside a closed container with a distinguishable removable wall that acted as a valve. However, Ray's computational model was also accurate, including some elements like the particles outside the container that Elly omitted.

Despite doing as well as anybody in the computational activity, Ray's written reflection after the interaction in Transcript 2.2 included others' opinions but did not include her own. She used the words "as if," which indicated that she was not convinced of the others' critique, but she felt compelled to write the group's opinion. Her use of the term "a lot of people" showed that she did not necessarily consider all her peers in the same social category.

Elly's reflection included a combination of pronouns "we" and "they." She characterized some ideas as the group's consensus, some as only Seven and Grant's opinion, and some as only her and Ava's opinion, which showed that she did not subscribe to Grant's characterization of the group consensus from Transcript 2.2. Her wording indicates that she may not have considered herself in the same social category as Seven and Grant. However, she also omitted Ray's opinions, which indicates that Ray's opinion, as someone not into computers, did not factor in Elly's evaluation of the modeling sandbox activity.

In contrast to Ray and Elly, Seven's understanding of how an air duster works was erroneous, impacting his engagement with the modeling sandbox. He conceptualized compressed air as a single entity and the air duster as an opaque system. His computational model comprised solid walls, and he grouped gas particles so close that they looked like a continuous stream. That is why he thought the sandbox was missing enough tools. He was brief and firm in his post-reflection, confirming that he was convinced of his knowledgeable insider status and that others' feedback did not influence his thoughts.

TABLE 4 A summary of the student's coursework before Transcripts 2.1 and 2.2 and their written reflections after the interaction.

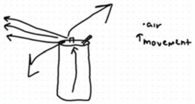
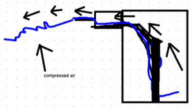
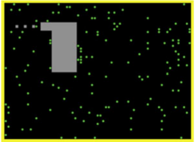
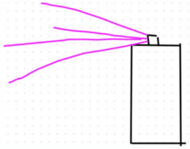
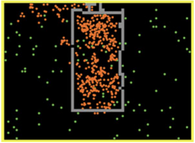
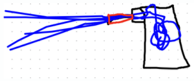
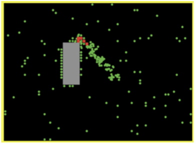
Student	Textual answer (verbatim)	Sketch	Computational model		Written reflection (verbatim)	Signaled identities
AMY	The paper pushes away the air gets more dense			CCLE	I wouldn't extend the tools because I think I can get much done.	Outsider (not into computers)
ELLY	Air is released through the valve when pressure is applied to the nozzle. The inside of the can loses pressure while the air is expelled. Outside of the can, the air is released and expands.				No particle differentiation when you overlap the tools. We agreed that there weren't enough tools to work with. They thought there should be more shapes for the tools and a different canvas options. We thought the toolkit was a little too buggy.	In-between, closer to the insiders
GRANT	The compressed air shoots out and has enough power to move light objects. The compressed air leaves the can and goes through a small tube which it shoots out from. When the valve is pressed, the air is moved out of the can quickly like deflating a balloon.				The class agrees that there are not enough tools for the sandbox toolkit.	Insider (into computers)
RAY	The compressed air leaves the can because of all the pressure. Outside the air shoots out and moves the paper, unlike the first time. Inside the can, the air molecules are moving very fast and pressing the valve is releasing the can of pressure from the can.				A lot of people felt as if the tools they were given were not enough.	Outsider (not into computers)

TABLE 4 (Continued)

Student	Textual answer (verbatim)	Sketch	Computational model		Written reflection (verbatim)	Signaled identities
SEVEN	The compressed air shoots out and moves light objects. The compressed air leaves the can and goes through the small tool and shoots out like a fan. The air moves out of the can quickly, like deflating a balloon.				Not enough tools.	Insider (into computers)

Abbreviation: CCLE, classroom computational literacy event.

Finally, Grant's and Seven's written explanations, hand-drawn sketches, and static computational models were similar. This indicates that Grant and Seven collaborated extensively during these activities, which is supported by our video data. However, Grant used the term “the class agrees” to start his written reflection on the activity, indicating that he may have disregarded Ray's and Elly's opinions and accepted Seven's criticism of the computational modeling sandbox as the group's consensus.

Overall, Transcripts 2.1 and 2.2 and the supplementary coursework data provide enough evidence to conclude that what happened in the classroom had much to do with how each student perceived others and themselves. At times, this went as far as skewed self-evaluations. Seven saw himself as a knowledgeable person and probably saw others' reactions to his remarks (e.g., Grant) as affirmations of his social identity claim, which led him to believe that his failure in the activity was due to the defects in the modeling sandbox toolkit. Ray saw herself as not into computing, which made her an outsider, which impacted how she perceived her apparent success in the activities before these interactions.

4.3 | The embedded CT activities challenged the students' stereotypical perceptions of computing at school

So far, we have shown that our focal group identified two salient social categories: those who are into computers and those who are not. We have also shown that even if a student did not explicitly claim one of these two social identities, others made implicit assumptions about their social identity. For example, we showed how Ray implied her belief that those who are into computers would be more capable of completing the CT activities in the unit than those who are not. Similarly, we showed how Ms. Bee implied her belief that Grant, a White male student, would be into computers. However, we also observed some encouraging impacts of the CC2 unit in problematizing such stereotypical beliefs and challenging the polar social categories established by our focal group students.

Transcript 3 presents an interaction between the first author, Mr. A, and Ray, where Ray articulates her perception of the unit with references to her social identification. As a participant observer, Mr. A did not have a microgenetic agenda during the implementation and was unaware of the CCLEs we presented so far. He approached the group to collect their feedback on the quality of computational activities, their content learning, and their perception of CT activities in the unit. His first question to Ray was open-ended, but Ray knew that Mr. Ae wanted to hear their feedback for the CC2 unit because he turned to Ray shortly after having a brief conversation with Seven on his critique of the computational modeling toolkit.

Transcript 3

Lesson 3, Lesson 2

62	MR A	What do you think Ray?
63		Your name is Ray ⌉ right?
64	RAY	⌊ This is boring
65	MR A	Why is it boring? Tell me.
66	RAY	Because I don't like
67		⎱ I'm not into this type of stuff
68		in the profession I wanna pursue there ⌈ isn't =
69	MR A	⌊ Ah!

70	RAY	⌈ Any computer stuff
71	MR A	⌊ What's the profession you want to pursue?
72	RAY	I wanna be a teacher
73		⎱ A kindergarten teacher so+
74	MR A	Oh
75		But we would like to ⎱
76		teach the kids about ⎱ how objects ⌈ work right?
77	RAY	⌊ Yeah
78	MR A	Like if something falls ⎱ if something hits something
79		⎱ Why do you think this is=
80		Do you think this is over the top?
81		Too complicated?
82		∘ Or this is like ⌈ too boring?∘
83	RAY	⌊ No.
84	RAY	I think it's for somebody who doesn't code all the time
85		I think it's perfect actually
86		But I mean like ⎱ ⎱ it's just not fun
87		But I don't think it's over the top
88	MR A	⌈ I see
89	RAY	⌊ It's like you give us the perfect amount for us to understand
90		But like not too much
91		We don't get like *super* confused
92	MR A	I see ⎱ but not interesting personally?
93	RAY	*(nods)*

We argue that this interaction between Mr. Ae and Ray provides evidence for two findings. On the one hand, Ray's statements at Lines 64, 67, and 86 confirmed the interplay between her social identity and her engagement with the CC2 unit. In doing so, she expresses a stereotypical perception of computing as relevant to only specific kinds of professions. However, Ray also had a meaningfully different experience with the CC2 unit compared to another experience in middle school when other students completed the coding activities for her (Transcript 1). This time, she completed the CT activities independently and successfully (Lines 39–44 and Table 2). In other words, the CC2 unit offered Ray a nonstereotypical engagement with computing.

Transcript 4 presents another CCLE where the focal group students had to make sense of a situation that could not be easily explained based on the polar social categories established earlier in the unit. This interaction happened when Ms. Bee asked another student, Moss (White male), to join our focal group to discuss the strengths and weaknesses of a predeveloped computational model in the unit. Moss mentioned to the others that he “hacked the code” of the model and made the model “crash.” He then went on to show them how he changed the model's code. In doing so, he gave them the impression that he was into computers and thus was in the same social category as Grant and Seven. However, when Ray attempted to confirm Moss' social identity by asking if he took coding classes at school, Moss responded negatively. In contrast to Grant and Seven, who expressed earlier that they enjoyed an after-school coding workshop (Transcript 1), Moss signaled a third kind of social identity: someone who likes coding but does not like coding classes at school. The subsequent interaction showed that our focal group students did not expect Moss' reaction, and they struggled to make sense of his social identity.

Transcript 4

Lesson 4, Lesson 2

Line	*Speaker*	*Message Unit*	*Interaction Unit*	*Non-verbal behavior*	*Identities Signaled in the Message Unit*
94	MOSS	There you go+	1	Moss is standing up and he shows his laptop's screen to the others.	Moss claims the social identity of someone who is good at coding.
95	RAY	Have you ever taken a coding class *before* Moss?	2	Ray looks at Moss.	Ray validates Moss' social identity claim.
96	MOSS	No.	↓	Moss leans on the desk while standing up.	
97	RAY	Do you want to?	↓		
98	MOSS	At the school? No.	↓	Moss looks at Ray, shakes his head negatively.	Moss claims the social identity of someone who is not into coding classes at school.
99	SEVEN	I, I did== ⎤ ⍰ ⍰ ⍰ ⍰	↓	Seven looks at Moss.	Seven claims the social identity of a person who is into coding classes at school.
100	MOSS	⌊ Because both my brother and sister went to	↓		
101		they both say it's atrocious	↓		
102		⎱ and my brother knew how to code while going to the class	↓		Moss positions his brother as someone who is into coding.
103		and he said it was still atrocious	↓		
104	RAY	Oh ⎱ like ⌈ real code?	3		
105	SEVEN	⌊ *It's not that bad+*	↓	Seven looks at Moss.	Seven positions Moss as an authoritative voice in the group.
106	RAY	Or like ⌈ block code?	↓		
107	SEVEN	⌊ It's *really* not that bad+	↓	Seven looks at moss.	
108	MOSS	Like probably code	↓		
109	RAY	Oh ⎱	↓		
110	SEVEN	It's really not that bad+	↓		
111	MOSS	Well, my brother and sister did it	↓		
112		They say it was atrocious	↓		
113	RAY	Well, you got to *think*	↓		Ray positions Moss as someone who is closer to her social identity than Seven's.Ray claims the social identity of a skeptic.

Moss's reasons for not wanting to take coding classes further complicated his social identification. He explained that his brother and sister took coding classes and told him that "it was atrocious" (Lines 100–103). He also mentioned that his brother knew coding beforehand but still found the coding class atrocious. In doing so, he signaled his siblings' social identities, but only vaguely. For example, it was not clear whether he was aligning his social identity with his brother's by mentioning that his brother knew coding before taking the class or whether he was simply attempting to highlight the level of atrociousness of coding classes. On one hand, Ross was a White male student who enjoyed coding, like Grant and Seven. On the other hand, he disliked coding classes at school, like Ray.

This CCLE also further confirmed that Ray and Seven saw each other in opposite social categories and were attentive to the others' social identification. Ray was particularly interested in understanding why Moss did not want to take coding classes because he otherwise matched her implicit criteria for being into coding. In doing so, she revealed some of her criteria for socially identifying others with respect to computing. For example, when Moss said he did not take any coding classes, she asked whether he wanted to do so in the future. When Moss mentioned that his brother knew coding before taking coding classes at school, she asked him if his brother knew "real code" or "block code" (Lines 104 and 106).

Seven's reaction to Moss was different than Ray's but showed that he was attentive to the markers of social identification in others' behavior. In previous CCLEs, Seven socially identified as being into coding but never engaged with Ray directly. In this CCLE, he first followed up with Moss's initial response "At the school? No!" (Line 97) by saying "I did" (Line 99) and then addressed Moss directly to challenge his depiction of coding classes as "atrocious" (Lines 105, 107, 110). There may be two alternative explanations for Seven's reaction. First, he might have tried to convince Moss that coding classes are not atrocious because he socially identified Moss as "into computers." Alternatively, he may have felt that Moss was unknowingly criticizing his social identity because he previously told Grant and Ray that he had taken and enjoyed coding classes at school (Transcript 1). In either case, Seven signaled that social identification played a key role in perceiving Moss's comments because he never directly responded to Ray's earlier critical remarks or told her that coding was not that bad.

5 | DISCUSSION

The results of our microethnographic analysis indicate that social identification played a meaningful role in our focal group students' chemistry learning with CT activities. There are four direct outcomes of our analysis. First, we find that the students' social identities with respect to computing became visible early on and remained visible throughout the unit. Second, we document the kinds of interactions that prompted social identification and various ways students socially identified themselves or others. Third, at least for Ray, we find a meaningful interplay between social identification and learning. Fourth, we show that integrating CT into a chemistry unit allowed students to engage with computing in nonstereotypical ways.

5.1 | Significance of our findings

We argue that our study makes a significant contribution to the science education literature because we provide evidence on how an interplay between social identification and the sociocultural implications of CT integration may influence students' science learning. Two threads of continuity between our study and prior research that highlight the significance of our findings: (1) the presence of race and gender as unspoken themes underlying the divisions within the focal group students and (2) the role of classroom dynamics on the interplay between social identification and learning with CT.

It is impossible to make causal claims on the role of our focal group students' racial background and gender on their social identification and science learning. However, it is equally impossible to ignore the presence of these themes in our CCLEs. On the one hand, our sample size is small, and none of the students explicitly mentioned race or gender in our data set. Therefore, there may have been other unexpressed factors underlying the students' behavior. On the other hand, our focal group was almost immediately divided into two subgroups: Grant and Seven, two White male students, were into computers, and Ray, a Black female student, was not (Transcript 1). Furthermore, Grant and Seven expressed their enjoyment of computing on multiple occasions (e.g., Transcripts 1 and 4), whereas, Ray found computing boring and irrelevant to her career goal of becoming a kindergarten teacher (Transcript 3). Third, Ms. Bee readily accepted Ray's social identity and subsequently positioned Grant in the opposite category (Transcript 2.2). Lastly, we noticed that Moss (White male) and Elly (White female) were socially identified as closer to the "into computers" social category by our our focal group (Transcripts 2.2 and 4), whereas Ava (Black female) posted a written reflection that indicated her agreement with Ray (Transcript 2.2 & Table 4).

The emergent division in our focal group indicates that previously documented issues concerning race and gender in CS education may begin impacting science education with the accelerating rate of CT integration. Research shows that most students who take elective CS courses at K-12 level are White or Asian male students (DuBow & Pruitt, 2019; McAlear et al., 2018; Sax et al., 2020; Wyatt et al., 2020), and students like Ray, who hold intersectional identities, report the lowest interest in computing (Google LLC & Gallup, Inc., 2016, 2020). Female and BIPOC students prefer not taking CS courses, even if they have access to CS offerings, because they see CS as a discipline that requires adopting a monolithic, socially isolated style of thinking and knowing (Gal-Ezer et al., 2009; Martin & Fisher-Ari, 2021; Master et al., 2016; Turkle & Papert, 1992). These earlier results suggest that the themes that emerged in our CCLEs may not be unique to our focal group students' local context. Integrating CT into science curricula without taking race, gender, and intersectionality into account may result in inadvertently disadvantaging female students and students of color. Conversely, as Kafai et al. (2020) and Wilensky et al. (2014) argued, anticipating social identification and designing appropriate interventions may help introduce students to a literacy-first depiction of computing, which could gradually culminate in improved science learning experience for female students and students of color.

Our findings also show that classroom dynamics and teacher involvement play a crucial role in determining whether differences in students' social identification will eventually result in differences in their learning trajectories. Although macrolevel issues may influence how students establish social identities in the classroom, the subsequent spontaneous interactions may determine whether those not into computers can benefit from CT-ified science education as much as those who are into computers. Our CCLEs show that Ray had a notably different experience throughout the CC2 unit than Grant or Seven. For example, although Grant and Seven were not hostile to Ray, they interacted with her negatively in various subtle ways, such as ignoring her remarks (Transcripts 2.2 and 4) or expressing opposing ideas about computing (Transcripts 1 and 4). Moreover, even Ms. Bee, an experienced Black female science teacher, implicitly validated Ray's social identity by positioning Grant as "into computers" immediately after Ray stated that she was not into computers (Transcript 2.2). These spontaneous interactions adversely affected Ray's learning trajectory by validating her misplaced belief that she must have succeeded in a CT activity because she knew less about computing than Grant and Seven (Transcripts 2.1 and 2.2).

Our study presents only one case on how social identification may play a nontrivial role in the emergence of learning disparities from local classroom dynamics. However, prior research in both STEM education and CS education shows that male students often dominate group projects and small group discussions at school in ways that perpetuate gender stereotypes (Butler, 2000; DuBow & Pruitt, 2019; Silverman & Pritchard, 1993) and exposure to such negative group work hinders female students' science learning and future career decisions (Riegle-Crumb & Morton, 2017; Wieselmann et al., 2020). Thus, integrating CT into science curricula without close attention to classroom dynamics may increase the frequency of adverse social interactions for students who are not into computers. At the same time, training teachers on how to establish balanced participation within groups and how to notice social identification cues may increase opportunities for local interventions in similar situations.

5.2 | Implications for science education stakeholders

Our study highlights the complex nature of social identification in the classroom and the challenges science educators face in integrating CT into their curricula. First and foremost, our study highlights the need for more research on the sociocultural dimensions of CT integration into science curricula. Such studies may range from attempts to test the generalizability of our findings to develiping a sound theoretical foundation to guide future research in this area. For the immediate future, we argue that our findings imply four main takeaways for stakeholders such as teachers, curriculum designers, researchers, and funding bodies. First, our results show that we should anticipate nonuniform participation in units with CT activities, with some students displaying reluctance (or even skepticism) and some displaying increased enthusiasm. Second, we should anticipate female students and students of color to fall into the former category (i.e., not into computers) more often and incorporate their skepticism as a valuable contribution to learning activities as much as the enthusiastic students' contributions. Third, we should promote CT as literacy and strive to overcome the prevalent perception of computing as a monolithic way of thinking that is only relevant to those who wish to become software developers or pursue STEM careers. Finally, we should provide professional development opportunities for teachers to learn how to recognize social identification in the classroom and how to intervene when necessary.

5.3 | Limitations

Our study has three limitations. First, our data is rich regarding student interactions, and our analysis is in-depth, but our sample size is small. Therefore, further research is needed to test the generalizability of our findings. Second, investigating social identification was not a primary research goal when designing and implementing the CC2 unit. Therefore, we did not collect data that could help us further corroborate our analysis. Future research should incorporate post-implementation interviews with students and teachers to inform initial microethnographic analysis and, if feasible, post-analysis interviews to corroborate theoretical interpretations of signaled social identities. Third, our microethnographic analysis primarily focused on identifying and documenting social identity. Therefore, our discussion of the implicit presence of race and gender should be considered as a theoretically plausible argument instead of a causal claim. Future research should attempt to address this limitation by incorporating theoretical tools to measure and analyze the role of race, gender, and intersectionality in student interactions.

ACKNOWLEDGMENTS

This study was made possible through generous support from the National Science Foundation (grants CNS-1138461, CNS-1441041, DRL-1020101, DRL-1640201, and DRL-1842374) and the Spencer Foundation (Award #201600069). Any opinions, findings, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the funding organizations. We would like to express our deep gratitude to Dr. Wan Shun Eva Lam for lending us her expertise by introducing the first author to the study of classroom discourse, guiding us during the early stages of our analysis, and giving us invaluable feedback on the first draft of our paper.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Aslan, U., Horn, M., & Wilensky, U. (2024). Why are some students "not into" computational thinking activities embedded within high school science units? Key takeaways from a microethnographic discourse analysis study. *Science Education*, 1–28. https://doi.org/10.1002/sce.21850