# 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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## ABSTRACT

As computing has become a core component of modern scientific practice, increasing numbers of science educators are attempting to integrate computational tools and methods into their curricula. One potential benefit of this approach would be to broaden exposure to a more realistic characterization of science, particularly for students from backgrounds that have been historically marginalized. However, even though this approach has the potential to promote engagement with computing in a more purposeful manner as a tool to conduct scientific investigations, recent studies show that more exposure does not necessarily lead to better outcomes among girls and students of color when it comes to key metrics such as motivation to pursue further science education. It is imperative to investigate students' engagement with computing in science classrooms to find more impactful ways to promote equitable science education. In this paper, we present a microethnographic discourse analysis of the interactions among a racially diverse group of high school students during a chemistry unit with tightly integrated computational thinking (CT) activities. We find a salient interaction between the students' engagement with the unit and their social identification with publicly recognizable categories such as "enjoys coding" or "finds computers boring." Our findings imply that CT in science education can lead to numerous rich interactions that could, if leveraged correctly, allow educators to facilitate more equitable science classrooms. We discuss the implications of our findings on future work to integrate CT across science curricula and science teacher education.


Keywords: science education, social identification, discourse analysis, equity, computational thinking

## Introduction

The past decade in science education was driven by calls to achieve parity between science education and modern scientific practices (e.g., National Research Council, 2012; NGSS Lead States, 2013). A major implication of these initiatives has been the subsequent calls to tightly integrate computational thinking (CT) activities across science curricula because contemporary science increasingly relies on computational tools and methods (e.g., Denning, 2017; Sengupta et al., 2013; Weintrop et al, 2015; Wilensky et al, 2014). However, science educators that strive to integrate computing into their day-to-day classroom instruction must contend with some of the critical issues surrounding equity and inclusion that were documented in prior computing education literature. Research has shown that computing education environments disproportionately favor white and Asian males, while leaving girls and students of color behind (e.g., Kafai et al., 2020; Margolis, 2008; Pinkard, 2005; Scott et al., 2017). As computing is fast becoming a staple of science education, it is of critical importance 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 study on the interactions among a racially diverse group of high school students during their engagement with a chemistry unit that included tightly integrated CT activities. We argue that this specific research setting would be appropriate to investigate the sociocultural implications of integrating CT across science curricula based on three primary assumptions: (1) all students engage with computing during these implementations, not just those who enroll to elective courses; (2) computing is framed as a tool for making sense of the course content, not as the content itself; and (3) students learn CT-embedded science units from their regular science teachers and with their regular classmates in their regular classrooms, not from computer science teachers in computer labs. Therefore, our research setting provides an opportunity to investigate students' natural ways of interacting with the CT activities within a science classroom.

Our analysis focuses on the potential interplay between the students' engagement with the computational activities and their 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). We primarily focus on this construct because prior studies have shown that both the way students socially identify themselves and the way others socially identify them in the classroom directly impact their content learning (e.g., Esmonde, 2009; Gee & Handford, 2013; Honeyford, 2014; Langer-Osuna, 2011; Wortham, 2004). 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 unique insights on how to cultivate inclusive science learning environments of the future.

Our theoretical framework combines Wortham's (2004, 2006) theory of social identification and Bloome et al.'s (2005) microethnographic discourse analysis approach. By analyzing students' moment-by-moment interactions with the CT activities and with their peers, we aim to answer the following research questions: *Were there any indicators of students' social identification with respect to computing when students were engaging with a science unit that included CT activities?*

*If yes, what kinds of interactions led to students' expression and negotiation of their social identities?*

## Background

### Computational thinking in science and mathematics

The term computational thinking (CT) was first used by Papert (1996) to define the use of computational representations in constructing and expressing *powerful ideas (see also Papert, 1980)*. Wing (2006; 2014) revived this term to advocate for computing as a universal skill that would benefit every student. She argued that computational thinking should be added to every child's analytical ability, like writing and arithmetic. Today, the term CT is claimed by two diverging theoretical perspectives. The first perspective builds on Wing's conceptualization of CT as "thinking like a computer scientist" (2006, pp. 35). The proponents of this perspective advocate for widening access to computer science education, specifically computer programming, through initiatives like the K12CS Framework, mandatory computer science courses, and out-of-school programs (e.g., Barr & Stephenson, 2011; Brennan & Resnick, 2012; Wilson, 2014).

The second popular theoretical perspective on computational thinking invokes Papert's early conceptualization and theories of computational literacy proposed by Papert (1980), diSessa (2001), and Wilensky & Papert (2010). Advocates of this perspective argue that standalone elective-only CS courses are destined to deepen the underrepresentation issue in computing and call for integrating computing across secondary-level science courses and demonstrating how students can use computing to make sense of their world (Wilensky et al., 2014). Weintrop et al.

(2015) define computational thinking as a taxonomy of practices extracted from interviews with scientists and mathematicians that use computing in practice. Their CT-STEM taxonomy includes four main categories of computational practices: data, computational problem-solving, modeling and simulation, and systems thinking (Figure 1). Weintrop et al. argue that the CT-STEM approach would promote a more realistic view of modern science fields, deepen student's learning of science and mathematics, and reach a wider audience compared to standalone computing courses. The CT-STEM taxonomy is widely used as a design framework for teacher training programs (e.g., Kelter et al., 2021; Peel et al., 2020) and curricular units with tightly integrated computational activities (e.g., Guo et al., 2016; Thompson et al., 2020). Recent studies show that science units designed according to the CT-STEM taxonomy improve students' computational thinking skills and science content learning simultaneously (e.g., Guo et al., 2016; Irgens et al., 2020; Swanson et al., 2018).

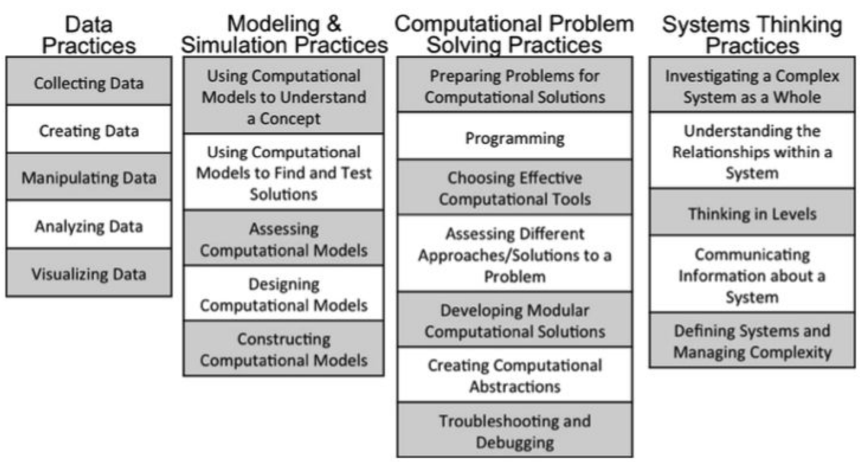



Figure 1: Computational Thinking in Science and Mathematics (CT-STEM) taxonomy (Weintrop et al., 2015)

The data we present in this paper was collected during the implementation of one such curricular unit, titled Anonymous Chemistry Unit (shortly ACU), that we designed according to the CT-STEM taxonomy and the prior research on teaching chemistry with computational tools. We hypothesized that the CT-STEM approach would offer opportunities to collect rich data on students' engagement with CT in otherwise familiar science classroom settings, which could in turn open possibilities to investigate patterns of social identification with respect to computing.

## Social Identification

Social identification is the process through which individuals and groups become identified as publicly recognized categories of people (Wortham, 2001; 2004). In order to be socially identified, a person must exhibit some characteristic or behavior that can be taken as a sign of a recognizable social type such as being "a dog person" or "a harsh teacher". Sociolinguistic studies show that there is a systematic interplay between how students learn content in the classroom and how they come to see themselves and others socially (e.g., Bloome et al., 2005; Wortham, 2004). Wortham shows that thinking of oneself as “good” or “bad” at a domain can be a salient aspect of identity, and the development of such an identity may in turn influence how much a student learns in the classroom (2004, pp. 731).

It is possible to study patterns of social identification across various timescales: social-historical patterns that develop over long periods of time, ontogenetic patterns that develop over the course of one's upbringing, local patterns that develop over days or weeks, and microgenetic patterns that develop over the course of short-term interactions. In this paper, we focus on the microgenetic level and we use the microethnographic discourse analysis method to do so. Bloome et al. (2005)

argue that teaching students to be readers and writers is as much a matter of "language socialization, enculturation, identity production, power relations, and situated interaction" as teaching how to manipulate symbol systems. Therefore, they foreground a view of classrooms as complex places where "teachers and students create and re-create, adopt and adapt, and engage in a full range of human interactions" (2004, pp. xvi). The microethnographic discourse analysis method describes how to systematically dissect interactions in terms of events, contexts, and settings as part of the worlds in which students and teachers live. We describe our use of the analytic tools developed by Bloome et al. in greater detail in the Data Analysis section below.

### Underrepresentation of Women and People of Color in Computing

Women and Black, Indigenous and People of Color (BIPOC) are significantly underrepresented in the computing fields. Only about 25% of the employees in computing-related fields are women and only 17% are BIPOC (USBLS, 2020). The workforce of the leading Silicon Valley companies is overwhelmingly White and male (Martin et al., 2015) and the number of male computer science (CS) journal article authors are dramatically higher than those of female authors (approximately 4-to-1 according to (Wang et al., 2019)). Girls and BIPOC students experience disadvantages in accessing high quality early computing education offerings, as well. For example, they are less likely to be offered CS courses than White and Asian male students (e.g., Fancsali et al., 2018; Google Inc. & Gallup Inc., 2016; Martin et al., 2015) and attempts to offer similar computing education initiatives lead to disproportionately higher gains in schools with predominantly White and Asian students (e.g., Salac et al., 2019).

Girls and BIPOC students report lower interest in CS (e.g., Google Inc. & Gallup Inc., 2016) and many of them see CS as a discipline for boys from dominant communities due to various reasons (Gal-Ezer et al., 2009; Master et al., 2016). Many students report that they did not prefer taking the CS offerings because they found the computing classrooms made up of mostly boys (Scott et al., 2017). Those who took CS courses risked negative attention from their peers and teachers. Boys were shown to be dominating group discussions and ignoring others' suggestions (Butler, 2000; NCWIT, 2020; Silverman and Pritchard, 1993). More importantly, the Google-Gallup (2016) study showed that the society at large unknowingly subscribed to the stereotypical perception of computing as a White male endeavor. Female students were less likely to be aware of CS learning opportunities and they were also less likely to be told by a parent or teacher that they would be good at CS. Lastly, the way CS was taught at K-12 level as a standalone, formal, and disconnected topic was shown to be influencing girls’ and BIPOC students’ perception of the domain (Turkle & Papert, 1992). These students reported that they preferred group work and collaboration; they did not like sitting in front of a computer for extended periods of time, and they wanted to pursue more immediately people-oriented domains (Carter, 2006; NCWIT, 2020). They also saw computing as antisocial and inattentive to communal goals (Diekman et al., 2010; Yardi & Bruckman, 2007).

All aforementioned biases and discriminatory policies are etched into the ethos of computing. A stereotypical perception of CS pervades society and it is acting as a gatekeeper that strongly favors White and Asian men. Not only are women and BIPOC systematically cut off from opportunities to enter computing, but also attempts to promote an equitable society are threatened.

Research shows that short-term interventions and specialized programs fail to make a dent in the fabric of computing (e.g., Scott et al., 2017). Many contemporary initiatives wrongly assume that simply increasing female and BIPOC students' exposure to computing would lead to more participation but recent studies suggest that more exposure does not directly result in increased participation (Ashcraft et al., 2017; Lang, et al., 2015; Scott et al., 2017). It is imperative to counteract the underrepresentation in computing with deliberate designs and interventions. That is why we specifically focus on a potential interaction between social identification and engagement with computational thinking activities in this paper. We argue that we need to expose how students come to see themselves and others as they are learning computing and learning with computing, if we are to improve the design of educational technologies, curricular units, and teacher training programs.

## Methods

We collected the data we report in this paper during the implementation of a curricular unit on ideal gas laws with embedded computational thinking activities that was designed as part of a larger study on the implications of integrating CT practices across STEM curricula (see also Anonymous Authors, 2020). We recruited two high school chemistry teachers to implement the unit. The site of the data collection was a public high school in the U.S. Midwest. The teachers Ms. Bee and Ms. Mel (pseudonyms) taught the unit simultaneously. The first author was present during the implementation as a participant-observer and we collected extensive qualitative and quantitative data. In this section, we describe the research implementation, curricular unit design, and data analysis methodology in detail.

## Research implementation

Ms. Bee was an African American chemistry teacher with 20+ years of experience, who retired just two weeks after this implementation. Ms. Mel was a White chemistry teacher with 10+ years of experience. Together, they taught a total of 7 tenth-grade classrooms and over 140 students and 121 of their students consented for research data collection. The sample was diverse in terms of gender and racial background (self-reported, Table 1).

The students used an online learning management system (LMS) to access the unit content. They also posted their class work (e.g., textual answers, sketches, screenshots, data sheets, computational models) on this LMS for the teachers to review. We collected all of the participating student's answers to a total of 110 questions on the LMS.

Table 1. Demographics of the study participants (self-reported).

| | *n* | *Male* | *Female* | *Non-binary* |
|---|---|---|---|---|
| White | 41 | 27 | 13 | 1 |
| African American | 34 | 14 | 20 | - |
| Latinx | 17 | 9 | 8 | - |
| Asian | 4 | 3 | 1 | - |
| Middle Eastern | 2 | 1 | 1 | - |
| Multiple | 23 | 14 | 9 | - |
| **Total** | **121** | **68** | **52** | **1** |

Ms. Bee taught the unit over 8 days in 4 different classrooms (n≈80) and Ms. Mel taught the unit over 6 days in 3 different classrooms (n≈60). As we developed the ACU unit with direct input from Ms. Bee and Ms. Mell, both of them were familiar with the unit and they did not have to alter their teaching styles to accommodate the computational activities. Both teachers opted to have their students form small groups and work autonomously because that was how they usually taught the previous units during the school year. In case all students from a particular group consented for audiovisual data collection, we marked them as a focal group and video recorded all of their interactions during the implementation. We were able to collect video data from 5 focal groups, 3 from Ms. Mel's and 2 from Ms. Bee's classrooms. We collected approximately 26 hours of video data in addition to 121 students' answers to the 110 questions on the LMS.



#### Curriculum overview: Anonymous CT-Embedded Chemistry Unit

The Anonymous Chemistry Unit (pseudonym for double-blind peer review, henceforth abbreviated as ACU for convenience) consisted of six lessons (Anonymous Authors, 2020). Each lesson contained tightly integrated CT activities that we designed according to Weintrop et al.'s (2015) CT-STEM taxonomy. The final unit included computational models, simulations, data analysis activities, programming activities, physical hands-on experiments, conceptual inquiry activities, small group discussions, and teacher-led discussions. The design of the computational modeling activities was heavily influenced by the GasLab modeling toolkit created by Wilensky (1999b; 2003) and the Connected Chemistry 1 (CC1) unit created by Levy & Wilensky (2006; 2009). We also adopted the unit structure from the CC1 unit. A summary of the whole ACU unit is presented in Table 2.

Table 2. Summary of the CC2 Unit

| Lesson Title | Length[1] | Content learning objective(s) | CT Practices |
|---|---|---|---|
| I - Introduction | 80 mins | Bootstrapping students' naive theories about the particulate nature of matter and Kinetic Molecular Theory | Computational Problem Solving<br>Modeling & Simulation<br>Systems Thinking |
| II - What is pressure? | 80 mins | Learning how micro-level interactions among gas particles lead to the emergence of pressure as a macro-level phenomenon. | Data<br>Modeling & Simulation<br>Systems Thinking |
| III - Number & pressure | 40 mins | Understanding the relationship between the number of particles in a container and gas pressure. Developing a mathematical model to express this relationship (corresponding to Avagadro's Law). | Data<br>Modeling & Simulation<br>Systems Thinking |
| IV - Temperature & Pressure | 40 mins | Understanding the relationship between the gas temperature in a container and gas pressure. Developing a mathematical model to express this relationship (corresponding to Charles' Law). | Data<br>Modeling & Simulation<br>Systems Thinking |
| V - Volume and Pressure | 40 mins | Understanding the relationship between the container volume and gas pressure. Developing a mathematical model to express this relationship (corresponding to Boyle's Law). | Data<br>Modeling & Simulation<br>Systems Thinking |
| VI - The ideal gas equation | 40 mins | Combining the three equations from the previous explorations to derive an ideal gas equation. | Data<br>Systems Thinking |



[1] Recommended length. A class period is assumed as approximately 40 minutes.

A detailed review of the whole ACU unit is beyond the scope of this paper, but we have included a summary of the first lesson to illustrate how we incorporated computational thinking practices with chemistry content. We believe this short introduction will be helpful when we are presenting our findings. We published results indicating positive outcomes in students' chemistry content learning and computational thinking skills after engaging with the ACU unit elsewhere (Anonymous Authors, 2020). The full unit and the accompanying teacher guide is published online (Anonymous Authors, 2020).

The first activity of the unit was an open-ended exploration of a real-world air duster canister as a simple real-world object with fixed volume and gas particles. The students had access to physical air dusters and they also watched a video on the LMS. The video showed a simple experiment with small pieces of paper used to compare an empty air duster to a one filled with pressurized air. When the valve of the empty air duster was pressed, the papers remained stationary. When the valve of the full air duster was pressed, the papers moved rapidly. After observing the air duster, the students wrote their hypotheses about what happens when the valve of the full air duster is pressed. Then, they illustrated their hypotheses with hand drawn sketches. At the end of this section, each teacher conducted whole-class discussions on the students' ideas by sharing some student sketches with the whole class and asking those students to explain their sketches. The teachers did not evaluate whether the sketches were correct or wrong.

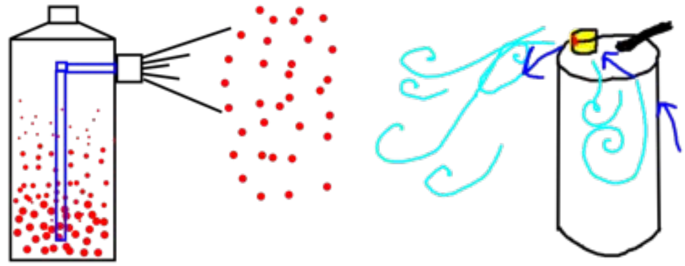


Figure 2: Examples from students' hand-drawn sketches

After the hypothesizing activities, the students created their own dynamic models of the air duster through a series of scaffolded computational modeling activities including a simple blocks-based coding environment. The modeling tools (Figure 3) were created with the NetLogo agent-based modeling environment (Wilensky, 1999a) and its NetTangoWeb blocks-based programming interface (Horn, Baker & Wilensky, 2020). The lesson included two more whole-class discussions and ended with a reflection activity. The second lesson built on the open-ended activities in this lesson to introduce the formal assumptions of Kinetic Molecular Theory to the students and the concept of pressure.

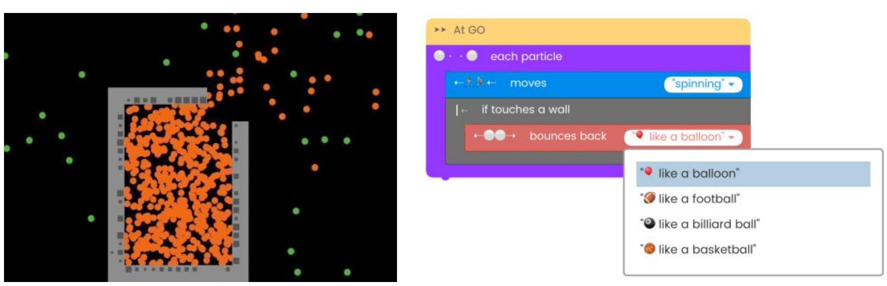



Figure 3: An example student computational model with the visual component (left) and the blocks-based programming component (right)

Prior research has demonstrated that computational thinking infused chemistry units would be a suitable setting to investigate our research questions (e.g., Levy & Wilensky, 2009; Stieff, 2011; Wilkerson-Jerde et al., 2015). First, kinetic molecular theory and ideal gas laws are foundational chemistry topics, so we assumed that the students would be able to engage with the unit in a normal science classroom. Second, prior research on the GasLab toolkit and the Connected Chemistry 1 unit showed a significant increase in science content learning (Levy & Wilensky, 2006; 2009; Wilensky, 1999b; 2003), so we assumed that the computational activities would not overpower the science content. Lastly, we designed the ACU unit primarily for promoting content learning and computational literacy. We did not embed any identity-related or equity-related components so that any social identity related interaction would emerge naturally, not as an artifact of the intervention.

## Data analysis

We used the microethnographic discourse analysis method (Bloome et al., 2005) to analyze the focal group recordings. We began our analysis by watching all focal group video recordings and marking potential instances of classroom computational literacy events (CCLEs). We defined CCLEs as an extension of Bloome et al.'s term *classroom literacy events (CLEs)*. Bloome et al. describes CLEs as cultural practices involving the use of written language associated with "doing classroom life" (pp. 50). Accordingly, we define CCLEs as cultural practices involving students' use of the computational thinking practices associated with the way they did classroom life.

Once we finished our initial scan for potential CCLEs and reviewed some of the field notes taken by the first author during the classroom implementations, we decided to choose a focal group from one of Ms. Bee's classrooms. The members of this focal group were Ray, an African American female student, Seven, a White male student, and Grey, another White male student (all pseudonyms). We picked this specific focal group for microethnographic discourse analysis primarily because its demographic composition was conducive to our research goals. However, we also chose them because there were enough indicators that these students did not alter their daily classroom practices during data collection. They chatted among themselves about the computational activities, the subject matter, and even out-of-class matters continuously. Lastly, Ms. Bee occasionally asked different student groups to get together and discuss the learning activities. These larger group discussions provided us with additional rich student interactions to analyze.

Once we picked our focal group, we watched all of their video data again and extracted shorter clips with potential CCLEs. After a final round of review, we narrowed down the number of clips to 10. Then, we transcribed each clip and conducted microethnographic discourse analysis using the following four constructs from Bloome et al. (2005):

1. **Contextualization cue:** any feature of linguistic form that contributes to the signaling of contextual presuppositions (e.g., pausing, stress patterns, intonation, changes in volume, speed of delivery, stylistic changes).
2. **Message unit:** the smallest unit of conversational meaning. The message units are identified through participants’ use of contextualization cues.
3. **Interactional unit:** A series of conversationally tied message units.
4. **Thematic coherence:** the organization of a set of meanings in and through an event. In other words, the answer to the question "What is this event about?" and "What is it that they are all talking about?"

In our analysis, we used contextualization cues primarily to determine the boundaries of message units and to divide students' verbal remarks into self-contained message units. Once we prepared each transcript as a series of message units, we determined the interactional units within each transcript by determining which message units were tied to each other and which message units started a new interaction. In some CCLEs, we only observed one interactional unit, but when we observed multiple interactional units, we used thematic coherence to determine when a CCLE started and when it ended. After preparing each CCLE according to these four constructs from Bloome et al. (2005), we watched each CCLE to extract students' non-verbal behavior during each message unit and we determined the social identities signaled in each message unit. In addition, we developed the transcription key presented in Table 3 to systematically mark and present the contextualization cues that we observed in each message unit such as pauses, interruptions, elongated vowels, and change in pitch.

Table 3: Transcription Key

| Symbol or format | Description |
|---|---|
| ⌊ | Short Pause |
| ⌊⌊ | Medium Pause |
| ⌊⌊⌊ | Long Pause |
| ⌈ ⌊ | 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 |
| *(…)* | Nonverbal behavior or transcriber comments for clarification |

Lastly, we reviewed the associated multimodal data produced by the students on the LMS such as summary tables, written reflections, hand-drawn sketches, and dynamic computer models. These materials allowed us to contextualize group discussions and gain additional insight on how to interpret our microethnographic findings.

## Findings

From their very first encounter with the computational activities in the unit, Ray, Seven, and Gray had numerous conversations among themselves. They discussed their past experiences, their perceptions of computing, their opinions on the ACU unit itself, and even their career choices. We were able to establish the answer to our first research question at the early stages of data analysis: there were indeed indicators of social identification when the students were engaging with the computational thinking activities in the unit.

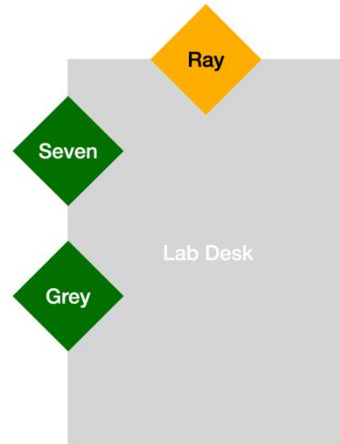
We uncovered several patterns of interactions that led to students’ expression and negotiation of their social identification in our analysis. We found that the students’ social identification was strongly informed by their past encounters with computing. They came to the classroom with already formed beliefs on which social category they belonged. However, the ACU unit offered them non-stereotypical encounters with computing and chances to negotiate their social identities. Another very salient pattern was that others’ claims of authority or success impacted how each student defined their own social identities, and yet the actual success in computational activities did not directly correlate with improved attitude towards computing.

We present our findings in chronological order with detailed transcripts and thick descriptions of each classroom computational literacy event because, echoing Bloome et al., we conceptualize classroom computational literacy events as dynamic and fluid events and we attempt to provide "thick descriptions in motion" (2005, pp. 52). Although we analyzed a total of 10 CCLEs in this study, we present only four of them in this paper because these four events illustrate our findings particularly well and taken together, they form a narrative arc that help us answer our second research question. In Transcripts 1, 2.1, and 3, we use a simplified transcript format because each of these transcripts contain only one interactional unit. However, in Transcripts 2.2 and 4, we present two CCLEs in a detailed table format primarily because they include multiple interactional units but also because we want to illustrate our microethnographic discourse analysis process explicit to the readers.

### Students began expressing the social identities they formed during prior encounters with computing when they engaged with the first embedded computational thinking activity in the unit

Throughout the unit, Grey, Ray, and Seven made numerous references to earlier encounters with computing, often using the term "coding" interchangeably with computing. It was quickly established that Ray had at least one unpleasant encounter with coding in the past, while Grey and Seven had positive experiences. Transcript 1 below shows the interaction that followed their very first encounter with a computational activity in the unit (see Table 3 for the transcription key).

Transcript 1: Lesson 1, Day 2




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

It was clear from Ray's remarks at lines 3 & 4 and the change in her intonation that she was genuinely surprised when she saw a computational activity in this chemistry unit. Perhaps due to this surprise, she told her friends that she did not know coding and she clarified that she did not "even know how to block code" (lines 5 & 6). We interpret Ray's remarks as an indication of her deliberately distancing herself from coding altogether and clarifying that this was not just due to the perceived difficulty of coding because blocks-based programming is a popular visual modality that is often considered easier than text-based programming (e.g., Bau et al., 2017; Weintrop & Wilensky, 2015). Her remarks at lines 7 & 8 on how she avoided doing a coding activity at middle-school supports this interpretation. Therefore, we argue that Ray already expressed her social identity with regards to computing as someone who equates computing with coding and does not see herself successful at it.

Seven and Grey’s reactions were slightly more muted and implicit, but they exhibited indicators of social identification, as well. At line 9, Grey interrupted Ray and asked others if they remembered the Hour of Code, which is a popular short-term standalone workshop offered by a non-profit (Wilson, 2014). 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 critical tone and expressed positive sentiment at line 12. Seven, on the other hand, confidently stated that he knew code at line 11, but him smiling while saying it indicated that he had an affinity for coding. Therefore, we interpreted the boys’ remarks as acknowledging Ray’s social identity as someone who does not like coding, seeing it as normal, and positioning themselves in an opposite social category of students who *know and like* coding.

We argue that this short interaction among Ray, Seven, and Grey already suggests a partial answer to our first research question; that is, there was an interaction between these students’ engagement with the embedded computational thinking activities and their social identification. For our second question, we argue that this interaction at least provides clues on ontogenetic influences on social identification at this classroom; that is, social identification did not only happen as a response to the activities at hand or any other classroom dynamics, but as a continuation of the students’ prior engagements with computing.

### Other peers' claims of confidence and knowledge in computing impacted one's social identification

Another salient aspect of the students’ identification was their perception of others’ success, knowledge, or confidence in computing. We present two successive interactions from the third day of the implementation to illustrate this finding. Both interactions happened after students were provided a static modeling toolkit which allowed them to recreate their hand-drawn sketches with computational building blocks: they could add static walls, they could add removable walls, and they could add 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 Amy (Black, female), to join Ray, Seven, and Gray to discuss a computational sandbox that students used to create a virtual air duster model. 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 very beginning of this discussion activity.

<u>Transcript 2.1: Day 1, Lesson 1</u>

ELLY ? ? ? ? get it to like actually upload+
RAY Oh. I didn't have any problems ⌉
SEVEN ⌊ Just not enough tools ⌋ ⌋ *(shakes head)*
and the particle
You can’t see the particles

| | | |
|---|---|---|
| 6 | | If you put like squares and like |
| 7 | | If there== |
| 8 | | If the object is filled with squares |
| 9 | | you can’t see the particles in it |
| 10 | | It doesn’t like ⎩ ⌈ doesn’t go. It doesn’t overlap+. |
| 11 | ELLY | ⌊ Oh yeah+ there is not like differentiation ⍰ ⍰ ⍰ ⍰ |
| 12 | SEVEN | It just like ⎩ ⎩ it's just a whole different surface |
| 13 | RAY | Oh+ |
| 14 | | ⎩ I didn't have any problems+ |
| 15 | | *But I'm not like a computer person either* |
| 16 | | So that’s probably why my opinion was |
| 17 | | "It's cool" |
| 18 | | "There were enough tools" *(smiles)* |

As her remarks at line 1 show, Elly initiated the discussion with negative remarks about a file uploading tool on the LMS. She used the term "upload" that indicated 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 3 through 12), which prevented him from achieving his goals. He also interrupted Ray’s attempt to respond at line 3 and ignored Elly's initial comments altogether, which indicated that he was probably oblivious to their answers altogether. At line 11, Elly affirmed Seven’s arguments, which indirectly affirmed his social identity as a student who knew computing and who did not like this modeling sandbox activity.

At lines 13 through 18, Ray did not only just state her own contradictory opinion to Elly and Seven, but she also actively positioned herself in an opposite social category. She expressed that she did not have any problems with the sandbox at line 14 and even smiled when she said "there were enough tools" at line 18. However, she immediately cautioned that she was "not a computer person" at line 15 and that her perceived success with the sandbox activity must have been due to her being different from Seven and Elly. We argue that her remarks were a direct response to Seven and Elly's social identification. As someone who did not claim confidence in computing, her perception of others' social identities was critical in how Ray perceived her own achievement.

Just when Ray finished her remarks, Ms. Bee approached the group. She asked, "Ray are you talking about the activity?" in a warning manner, implying that she suspected the group of chatting about non-relevant topics. In Transcript 2.2, we present our detailed microethnographic discourse analysis of the group's interaction with Ms. Bee, along with a detailed table of the non-verbal behavior and our interpretation of the student identities signaled in the message units.

Transcript 2.2: Description of social identities, Day 2 Lesson 1

| Line No | Speaker | Message Unit | Interaction Unit | Non-verbal behavior | Identities Signaled in Message Units |
|---|---|---|---|---|---|
| 1 | MS BEE | So, what's this discussion about over here? | 1 | Ms. Bee stands between Ray & Grey, looks towards Seven. | |
| 2 | AMY | We are talking | ↓ | | |
| | | ⌈ about the sandbox model = | | | |
| 3 | RAY | ⌊ The sandbox activity | ↓ | | |
| 4 | MS BEE | Ok. What about it? | ↓ | | |
| 5 | RAY | Well ⌈ they feel like | ↓ | Ray looks at her computer, doesn't turn to Ms. Bee. | Ray positions herself as an outsider. |
| 6 | SEVEN | ⌊ It's buggy. | ↓ | Seven looks at his computer, speaks while Ray's speaking. | Seven claims the identity of a knowledgeable person. |
| 7 | 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. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | AMY | And we == ⌉ | ↓ | | Amy points at Ray. | Amy attempts to claim the identity of an outsider. |
| 9 | RAY | ⌊*But* I said that<br><br>I feel like they shouldn't add anything | ↓ | | | Ray reiterates her claim of being an outsider, while ignoring Amy's attempt to join her. |
| 10 | | like I had the perfect amount of tools | ↓ | | | |
| 11 | | but like I'm not into computers and stuff like that | ↓ | | | Ray claims the social identity of a person who is disinterested in computing. |
| 12 | | 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. |
| 13 | | But for me ⎩ I guess it was enough | ↓ | | | |
| 14 | | I made the model | ↓ | | | Ray claims the identity of a successful student in this unit. |
| 15 | MS BEE | What do you say because you are into computers | | 2 | Ms. Bee turns towards Grey, pointing at him with her index finger. | Ms. Bee upholds Ray's social identification as disinterested and unknowledgeable in computers. She also socially identifies Grey as interested and knowledgeable in computers. |

| | | | | | |
|---|---|---|---|---|---|
| 16 | | 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. |
| 17 | GREY | ⌊⌊ I also | ↓ | Grey looks down, leans forward, and touches the desk. Pauses for a while. Then, puts his hands in his pockets | |
| 18 | | I just ⌊ | ↓ | | |
| 19 | | a bunch of people agree that | ↓ | Grey looks at his computer screen, scrolls the mouse, indicating that he is reading a text. | Grey takes on the role of the speaker of the group. Grey positions Seven and Elly as knowledgeable. |
| 20 | | Umm ⌊ | ↓ | | |
| 21 | | There is not enough like tools in the in thing ⌈ because | ↓ | | Grey accepts the social identity of interested computers. |
| 22 | MS BEE | ⌊ Like what kind of tools? | ↓ | Ms. Bee briefly glances at Grey's computer. | |
| 23 | GREY | It was just like ⌊ ⌊ ⌊ | ↓ | | |

| | | | | | |
|---|---|---|---|---|---|
| 24 | | There is an issue with like ⎩ ⎩ uploading like files ⎩ stuff like that for like for the toolkit ⎩ and yeah | ↓ | | |
| 25 | MS BEE | So, what would you add? | 3 | Ms. Bee turns from looking at Grey to looking at his computer. | |
| 26 | GREY | umm ⏋ | ↓ | | |
| 27 | 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. |
| 28 | GREY | Yeah, maybe a shape because like== ⏋ | ↓ | | |
| 29 | MS BEE | ∟ Shapes for the+ containers? | ↓ | Ms. Bee looks at Seven. | Ms. Bee accepts Seven's social identity. |
| 30 | GREY | Yeah | ↓ | | |
| 31 | SEVEN | um-hum | ↓ | Seven hums to indicate that he agrees with Grey's answer. | |

At lines 9 through 14, Ray simply repeated her remarks from Transcript 2.1 and mentioned again that she was successful in the activity because she was "not into computers." This time, she added, "somebody who does this stuff would know the difference" at line 12. Her expression of these ideas openly in the presence of Ms. Bee showed that she thought the existing social categories and her self-evaluation were not unusual. She also used the pronoun "they" at lines 5 and 7 to explicitly demarcate herself from the others in the group. Lastly, she ignored Amy's attempt to join her at line 8, probably because she wanted to finish her thoughts as others often interrupted her, such as Seven's interruption at line 6.

It was notable how readily Ms. Bee accepted the existence of the social categories that were made explicit by Ray's comments. She not only upheld the social categories that developed prior to her involvement with this group, but she also actively used Ray's exact words to position Grey as "into computers" at line 15. She said, "that's what she said" at line 16, but Ray did not explicitly name any of her peers or make any gestures towards any of them. Ms. Bee spontaneously considered Grey, a White male student, to fit in this social category but not Elly or Amy.

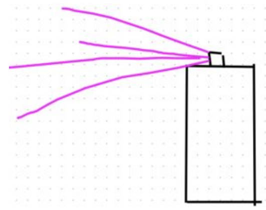
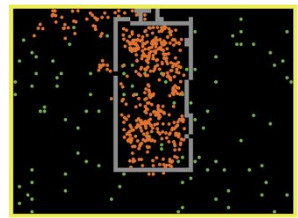
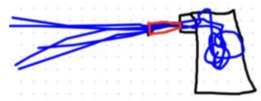
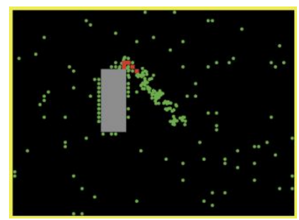
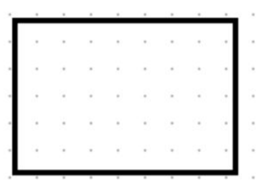
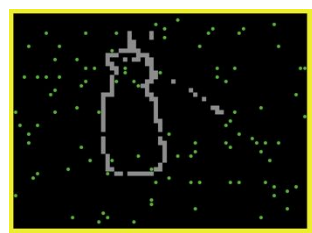
Grey responded to Ms. Bee's characterization positively, although it was clear that he was not comfortable answering her questions. In a way, his social identification was the exact opposite of Ray's. He was not doing well but being a member of the "into computers" social category gave him the confidence to assume the role of a spokesperson of the group. At line 19, he presented his remarks as the group's consensus, ignoring Ray's critical remarks prior. Both the substance of his answer and the non-verbal indicators showed that Grey was not confident in his knowledge. He basically repeated Seven's and Elly's comments. In doing so, he confirmed Elly's and Seven's social identity as into computers and excluded Ray from this social category. When confronted with a follow up question, he faltered only to be saved by Seven.

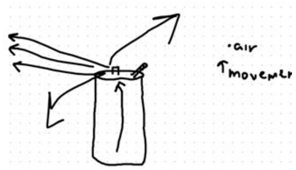
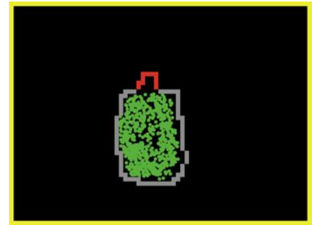
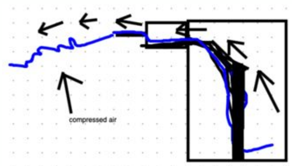
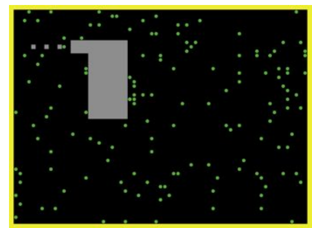
Seven showed extreme confidence once again and claimed the identity of an authoritative figure in computing throughout the interaction. Although he was never questioned by Ms. Bee directly, he interrupted others’ answers twice, once to claim the pronoun “they” used by Ray at line 6 and once to save Grey from a difficult follow-up question at line 27. His non-verbal behavior exhibited confidence, as well. He never directly looked at Ms. Bee or others while they were speaking. Although he kept looking at his computer and typed some text, he constantly intervened with short remarks such as in line 6, 27, and 31. He claimed the social identity of an insider, a person who is into computing, and a person who knows computing well.

Elly actually opened up the discussion along with Ray, but she was quickly sidelined by Ray & Seven, especially by Ray, who started speaking over Elly at line 3 and did not let Amy interrupt her at line 8. Amy did not participate in this interaction at all.

Both Transcripts 2.1 & 2.2 raised the question of whether each student’s claim of knowledge or achievement was informed by their actual coursework since Ray communicated success and Seven communicated failure. In places where these transcripts were vague or ambiguous, we referred to the multimodal data to gain additional insight. We present a summary of these five students’ multimodal data in Table 4. The multimodal data includes the students’ answers to some of the questions on the LMS prior to this CCLE, their written reflections after this CCLE, and our analysis of the social identities exhibited by their written reflections.

Table 4: A summary of the students' coursework prior to Transcripts 2.1 & 2.2 and their written reflections after the interaction

| *Student* | *Textual answer (verbatim, emphasis added)* | *Sketch* | *Computational model* | | *Written reflection (verbatim, emphasis added)* | *Identities signaled in the reflection* |
|---|---|---|---|---|---|---|
| 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. |  |  | Discussions in Transcripts 2.1 & 2.2 | **A lot of people** felt as if the tools they were given were not enough. | Outsider |
| SEVEN | The compressed air shoots out and moves light objects. The compressed air leaves the can and goes through the small toob and shoots out like a fan. The air moves out of the can quickly, like deflating a balloon. |  |  | | Not enough tools. | Knowledgeable, Confident |
| AMY | the paper pushes away<br>the air gets more dense |  |  | | **I wouldn't extend the tools** because I think I can get much done. | Confident |

| | | | | | |
|---|---|---|---|---|---|
| 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. |  |  | Discussions in Transcripts 2.1 & 2.2 | 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. |
| GREY | 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. |

| | |
|---|---|
| ELLY | Partial Insider, Partial In-between, Knowledgeable, Confident |
| GREY | Insider |

It was clear from their coursework before this CCLE (Table 4, columns 2, 3, and 4) that Ray and Elly did much better than the other three in these open-ended activities. Ray's written answer was the only one that mentioned air molecules moving fast and she mentioned the term pressure. Elly's computational model was the most scientifically accurate based on the fact that it included numerous particles evenly distributed inside a closed container with a distinguishable removable wall that acted as a valve. On the other hand, Ray's computational model was also very good, including some elements like the particles outside the container that Elly omitted.

Despite her doing as well as anybody in the computational activity, Ray's reflection after the CCLE just included others' opinions and she decided not to include her own opinions. Her choice of the term "as if" showed that she was actually 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 4 others 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 Grey's opinion, and some as only her and Amy's opinion. This showed that she did not subscribe to Grey's characterization of the group consensus from Transcript 2.2, and she did not necessarily consider herself in the same social category as Seven & Grey. However, she also completely omitted Ray's opinions altogether. This showed that Ray's opinion, as someone who is not into computers, did not factor in Elly's thinking.

In contrast to Ray and Elly, Seven's understanding of how an air duster works was incomplete and this impacted his engagement with the modeling sandbox. He conceptualized compressed air as a single entity and the air duster canister as an opaque system. His computational model was made up of solid walls and he grouped gas particles so close they looked like a continuous stream. That’s 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 his thoughts were not influenced by others’ feedback.

Lastly, Gray’s and Seven’s written explanations, hand-drawn sketches, and static computational models all were very similar. This indicates that Grey and Seven collaborated extensively during these activities, which is supported by our video data. However, Gray 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.

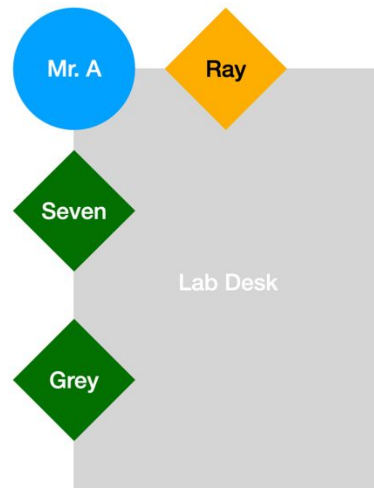
Overall, Transcripts 2.1 & 2.2. and the supplementary multimodal data provides enough evidence to conclude that what happened at the classroom had a lot to do with how each student perceived others and themselves. At times this went as far as skewed self-evaluations. Seven saw himself as a knowledgeable person and probably saw others’ reactions to his remarks (e.g., Grey) 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 not into computing and this made her an outsider, which impacted how she perceived her apparent success in the activities prior to these interactions. More importantly, most of the social identification was seen as normal and accepted implicitly without any push-back, even when it was as explicit as Ray’s remarks, “I’m not into computers.”

### The embedded computational thinking activities challenged prevalent stereotypical perceptions of computing at school

All social identities that became visible in Transcripts 1, 2.1, & 2.2 were due to the students' engagement with the very first computational activity in the unit but did not emerge in isolation. Many social-historical and ontogenetic factors inform the findings we presented so far. A stereotypical perception of computing was a main theme in many of the students' discussions. For example, Transcript 1 showed that Ray's perception of computing was informed by her not enjoying computing when it was offered as an isolated activity at middle school, which is consistent with Carter (2006), Turkle & Papert (1992), and NCWIT (2020). We also showed how the group was divided in terms of gender and race, which was expected from prior research studies (e.g., Butler, 2000; Google & Gallup, 2016). Therefore, it is essential for such CT in STEM implementations to offer students a non-stereotypical characterization of computing.

We present an interaction between the first author, Mr. A, and Ray in Transcript 3. At the time of this interaction, Mr. A was unaware of any interactions that we presented so far, and he did not have any microethnographic research agenda. He was present in the classroom as a participant observer and at times he approached the students to collect their feedback. His primary goal was to collect information on the instructional design of the unit. Ray's remarks in Transcripts 2.1 & 2.2 already hinted at her having a rather pleasant experience with the computational activity, but we decided to include this interaction, too, because it provides additional evidence on how Ray did not perceive the CT activities in the ACU as stereotypical computing activities even though she still ended up not showing positive affinity towards computing.

Transcript 3: Day 3, Lesson 2:




| | |
|---|---|
| MR A | What do you think Ray? |
| | Your name is Ray ⌉ right? |
| RAY | ⌊ This is boring |
| MR A | Why is it boring? Tell me. |
| RAY | Because I don't like |
| | ⎱ I'm not into this type of stuff |
| | in the profession I wanna pursue there ⌈ isn't = |
| MR A | ⌊ Ah! |
| RAY | ⌈ Any computer stuff |
| MR A | ⌊ What's the profession you want to pursue? |
| RAY | I wanna be a teacher |
| | ⎱ A kindergarten teacher so+ |
| MR A | Oh |
| | But we would like to ⎱ |
| | teach the kids about ⎱ how objects ⌈ work right? |
| RAY | ⌊ Yeah |

| | | |
|---|---|---|
| 17 | MR A | Like if something falls ⎩ if something hits something |
| 18 | | ⎩ Why do you think this is= |
| 19 | | Do you think this is over the top? |
| 20 | | Too complicated? |
| 21 | | ◦ Or this is like ⌈ too boring?◦ |
| 22 | RAY | ⌊ No. |
| 23 | RAY | I think it’s for somebody who doesn’t code all the time |
| 24 | | I think it’s perfect actually |
| 25 | | But I mean like ⎩ ⎩ it’s just not fun |
| 26 | | But I don't think it's over the top |
| 26 | MR A | |
| | | ⌈ I see |
| 27 | RAY | ⌊ It’s like you give us the perfect amount for us to understand |
| 28 | | But like not too much |
| 29 | | We don’t get like *super* confused |
| 30 | MR A | I see ⎩ but not interesting personally? |
| 31 | RAY | *(nods)* |

Ray’s immediate responses to Mr. A (lines 3-7) showed that she found computing incompatible with her career goals, which was to become a kindergarten teacher. Even though she explicitly used the term “computer stuff” at line 9, Mr. A clearly misunderstood her remarks and assumed that Ray must have found the chemistry content boring, as implied by his remarks at lines 15 & 17. That is also probably why at lines 18 through 21, he asked Ray whether she thought the activities were too complicated or “over the top”. Ray’s response that the activities were actually “the perfect amount” for students like her who “does not code all the time” (lines 22-29) confirmed that she differentiated between social identities of those who are into computers and those who are not. In addition, she invoked the term coding once again, which indicates that she used the terms coding and computing interchangeably.

Ray’s career choice was consistent with previous research and statistical data. An overwhelming majority of girls and BIPOC students do not envision themselves pursuing computing related careers (e.g., Google Inc. & Gallup Inc, 2016; Martin et al., 2015; Scott et al., 2017). We also showed in prior CCLEs that this particular classroom’s environment made the matters only worse. Mr. A’s interaction with Ray was another missed opportunity to allow her to critically engage with the concept of computing and encourage her to consider a non-stereotypical perception. It is also important to note that Ray probably perceived Mr. A as a stereotypical role model (White male), which was shown to be negatively impacting women's career aspirations in computing (Cheryan et al., 2012).

Another instance of a non-stereotypical characterization of computing emerged during the fourth day of the implementation when Moss, a White male student, joined Ray, Seven, and Grey for another discussion activity. The discussion activity was about a computational bike tire model which allowed students to pump virtual gas particles inside a container and then measure the change in pressure. When Moss joined the group, he mentioned that he “hacked the code” of the model and made it “crash.” His apparent show of confidence and knowledge in computing triggered another interaction around the social categories that emerged in the previous interactions (Transcripts 1, 2.1, & 2.2).

We present our detailed microethnographic discourse analysis of this CCLE in Transcript 4. The interaction starts from the moment when Moss managed to crash the web browser by running the model with 40000 particles instead of the default 400. He was able to change the code because all of the models embedded in the ACU unit had their code openly available to the students even when there were no direct coding activities. We included this interaction because Moss' engagement with the others showed how each student reacted when a student like Moss explicitly rejected being socially identified as either fully into computing or fully not into computing.

Transcript 4: Description of social identities, Day 4 Lesson 2

| *Line No* | *Speaker* | *Message Unit* | *Interaction Unit* | *Non-verbal behavior* | *Identities Signaled in the Message Unit* |
|---|---|---|---|---|---|
| 1 | 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. |
| 2 | RAY | Have you ever taken a coding class *before* Moss? | 2 | Ray looks at Moss. | Ray validates Moss' social identity claim. |
| 3 | MOSS | No. | ↓ | Moss leans on the desk while standing up. | |
| 4 | RAY | Do you want to? | ↓ | | |
| 5 | 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. |
| 6 | SEVEN | I, I did== ⌉ ⍰ ⍰ ⍰ ⍰ | ↓ | Seven looks at Moss. | Seven claims the social identity of a person who is into coding classes at school. |
| 7 | MOSS | ⌊ Because both my brother and sister went to | ↓ | | |

| | | | | | |
|---|---|---|---|---|---|
| 8 | | they both say it’s atrocious | ↓ | | |
| 9 | | ⎩ and my brother knew how to code while going to the class | ↓ | | Moss positions his brother as someone who is into coding. |
| 10 | | and he said it was still atrocious | ↓ | | |
| 11 | RAY | Oh ⎩ like ⌈ real code? | 3 | | |
| 12 | SEVEN | ⌊ *It's not that bad+* | ↓ | Seven looks at Moss. | Seven positions Moss as an authoritative voice in the group. |
| 13 | RAY | Or like ⌈ block code? | ↓ | | |
| 14 | SEVEN | ⌊ It's *really* not that bad+ | ↓ | Seven looks at moss. | |
| 15 | MOSS | Like probably code | ↓ | | |
| 16 | RAY | Oh ⎩ | ↓ | | |
| 17 | SEVEN | It's really not that bad+ | ↓ | | |
| 18 | MOSS | Well, my brother and sister did it | ↓ | | Moss accepts Seven's positioning of him as an authoritative voice in the group. |
| 19 | | They say it was atrocious | ↓ | | |

| | | | | |
|---|---|---|---|---|
| 20 | 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. |

Ray's initial questions to Moss at lines 2 & 4 show that she was curious whether Moss would also socially identify as into computers like Seven and Grey did in the previous interactions because Moss was excited to share his accomplishment with others, exhibited confidence in his programming skills, and used technical terms such as "code," "hacking," and "crash." It is also important to note here that Ray did not ask Moss if he ever did coding activities before, but she specifically asked about "coding classes."

Moss' answer "At the school? No." (line 4) and his intonation indicated a firm negative answer. It was possible to see from Seven's surprised reactions at lines 12, 13, and 17 that he did not expect Moss' to answer so forcefully. As we showed in the previous CCLEs, both Seven and Ray perceived computing as a rather rigid entity or concept dominated by coding, and they did not discriminate any sub-practices. Moss, on the other hand, differentiated between the coding in this chemistry unit and the coding classes at the school. His reasoning was socially and historically motivated; his siblings took computing classes at school before and they thought the classes were "atrocious." On one hand, he was more like Seven when it comes to showing confidence in his computing skills. On the other hand, he was more like Ray when it comes to his dislike of coding at school. In a way, his social identification counteracted the bipolar nature of the existing social categories that emerged during the previous three CCLEs. We already showed in Transcript 2.2 and Table 4 that Elly actually had a non-stereotypical experience, too, but she did not express it explicitly.

Ray's questions at lines 11 and 13 show that she was surprised of Moss' responses, too, and she was even skeptical of his remarks at line 9 about his brother regretting taking a coding class even though he knew coding beforehand. In Transcript 1, we showed how Ray specifically mentioned the term “block code” to imply that she did not like coding as a concept, not just because of its difficulty. Therefore, Ray’s question “like real code or like block code?” was an attempt to gauge the degree to which Moss’ brother was into computing before taking a coding class and finding it atrocious. Moss’ answer at line 15 implied “textual code”.

Seven’s first engagement with this interaction was when he tried to interrupt Moss at line 6 to tell the group that he took a coding class before, but Moss did not let him interrupt. When confronted with Moss’s atypical answer, Seven felt the need to claim that coding classes were “really not that bad” three times, with emphasis on “really” at lines 12, 14, and 17. Each time he mentioned his thoughts, he tried to interrupt Ray and Moss’ interaction. It was clear that Seven perceived Moss as knowledgeable in computing, and hence in the same social category with him because this was the first time Seven actually raised his head and directly looked at someone while speaking. He was invested in convincing Moss that coding classes were not bad, probably because he perceived Moss’ remarks as a judgment of his social identity.

Ray’s last remark at line 20 indicated that she probably interpreted this conversation as a rebuttal of Seven and Grey’s earlier remarks in Transcript 1 and a validation of her perception of computing at school as a boring and unpleasant experience.

We argue that the interaction among Moss, Ray, and Seven showed how promising such science units with tightly integrated CT activities can be when it comes to providing students diverse encounters with computing and pave the way for less polarized social categories. In addition, students can engage with computing critically in CT-STEM units, as Ray did during this implementation, instead of readily accepting its promoted value as most around them seemed to be doing. However, we also showed that such interactions simply failed to compel the students to reconsider their previously established social identities because they were left unattended and underleveraged. They defended their own social identities (i.e., enjoys coding versus not into coding) by trying to incorporate the non-stereotypical remarks made by Moss into their arguments, but they never seemed to consider the prospect of convincing others seriously. For example, Seven still ignored Ray's follow-up question "like real code?" and started speaking over her at line 14 to push back on Moss's characterization of coding classes as "atrocious." However, he never attempted to convince Ray that coding could be fun or useful. Similarly, Ray completely ignored Seven in this interaction and she never tried to convince others that they should be critical of coding.

## Discussion

Was this focal group an anomaly? Did we stumble into some extraordinary discussions that would not happen on most other CT-STEM implementations? We did not yet conduct similar microethnographic discourse analysis studies on the other 4 focal groups' video recordings but we observed some similarities during our initial review of the whole data corpus. For example, Y, a Black female student of Ms. Mel, remarked, "*my baby brother does this*" when she first saw the blocks-based programming activity in the unit. Y’s remark indicated an implicit association between coding and gender. Her groupmate, H, who was a Latinx female student, responded, "*they made me learn programming at middle school*", which indicated that she did not see herself as someone who would learn programming willingly. Therefore, we argue that the first and foremost implication of our findings is that there was a strong interaction between the students' social identification and their interaction with the CT activities when they were learning chemistry with the ACU unit.

It was also evident that none of the social identities or categories that emerged during the discussions were formed independently on the spot. Each student had previous experience with computing and each already subscribed to a stereotypical view of computing. Their existing identities became visible thanks to the CT activities. Social categories emerged, were negotiated, and were mostly upheld barring Moss' unique position. It is of course not surprising that any divergence that emerged in such interactions would only crystalize due to the strength of social, historical, and ontogenetic forces against local short-term interactions. However, we are optimistic that future designs that explicitly address the social identification dimension may succeed to make a dent in the popular perception of computing as racially and sexually segregated. Ray, who positioned herself as "not into computers," and Moss, who thought the coding classes at school were "atrocious," had non-standard experiences that pushed the envelope for them when it comes to encountering computing at school. More importantly, they were both successful in computing-related activities in the unit, often doing much better than other students who considered themselves as “into computing” and exhibited confidence in their computing skills.

We argue that our findings, in general, are also an affirmation of the characterization of CT from a computational literacy perspective (e.g., diSessa, 2001; Kafai et al., 2019; Wilensky & Papert, 2010; Wilensky et al., 2014) and a counter-argument against the coding-heavy perspectives (e.g., Wing, 2006; 2014). We were able to collect such rich data in the first place because Ray, Seven, and Grey already knew each other, collaborated on lab activities together all the time, were comfortable expressing their identity positions publicly, and were doing science learning in their everyday classroom as usual. Considering the scarcity of similar studies in the CS education literature, we argue that the likelihood of collecting similar data in a standalone CS course or workshop would be lower. Moreover, even Ms. Bee, an African American woman with more than twenty years of experience in teaching science at a racially diverse high school, was unable to notice how she readily accepted Ray's social identification of herself as "not into computers" and the others as "into computers" without much questioning. It is hard to imagine computer science teachers or workshop facilitators overcoming similar challenges without proper training and well-designed interventions. Vossoughi et al. (2013) argue that equity lies in pedagogical language, students' cultural and intellectual histories, and a widened meaning of STEM learning. Wilensky et al. (2014) similarly argue that our educational system needs to recognize the growing importance of computing for all members of society. We believe these two arguments strongly apply to computational thinking in science and mathematics. Future units and teacher training programs must attend to the interaction between social identification and CT and develop actionable solutions.

## Limitations

There are two limitations of this study that prevent us from making more generalizable claims from our findings on the interplay between social identification and engagement with the CT activities embedded within the ACU unit. Firstly, we presented our analysis of only 6 students' experiences, often concentrating on only three of them. Secondly, investigating social identification was not a primary research goal when we were designing and implementing the ACU unit. Therefore, we did not implement any measurement instruments (e.g., surveys, reflection questions, interviews) specifically targeted to expose students' socially identification. In addition, although we are hopeful that our study's findings and our methodological approach could indirectly contribute to the efforts on promoting equity in science education, we also acknowledge that this initial study did not include any direct research questions on race, gender, and intersectionality. A future study that specifically targets this limitation with a larger dataset and multiple focal groups could prove a significant contribution to science education literature.

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