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Cracking her codes: understanding shared technology resources as positioning artifacts for power and status in CSCL environments

Amber Simpson[1] **· Nicole Bannister**[2] **· Gretchen Matthews**[3]

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Abstract There is a positive relationship between student participation in computer-supported collaborative learning (CSCL) environments and improved complex problem-solving strategies, increased learning gains, higher engagement in the thinking of their peers, and an enthusiastic disposition toward groupwork. However, student participation varies from group to group, even in contexts where students and teachers have had extensive training in working together. In this study, we use positioning theory and interaction analysis and to conceptualize and investigate relationships between student interactions across two partner pairs working with technology in an all-female cryptography summer camp and their negotiated positions of power and status. The analysis resulted in uneven participation patterns, unequal status orderings, and an imbalance of power in both comparison cases. We found a reflexive relationship between partner interactions around shared technology resources and negotiated positions of power and status, which leads us to conclude that interactions around technology function as an important indicator of negotiated positionings of power and status in CSCL settings, and vice-versa. With that said, we found qualitative differences in the ways emergent

✉ Amber Simpson
asimpson@binghamton.edu

Nicole Bannister
nbannis@clemson.edu

Gretchen Matthews
gmatthe@clemson.edu

[1] Department of Teaching, Learning, and Educational Leadership, Binghamton University, Academic Building B, Room 242, PO Box 6000, Binghamton, NY 13902, USA Q1

[2] College of Education, Clemson University, Martin Hall, Room O-04, Clemson, SC 29634, USA

[3] Department of Mathematical Sciences, Clemson University, Martin Hall, Room O-18, Clemson, SC 29634, USA

status problems impacted each team's productivity with the cryptography challenge, which has important implications for future research on CSCL settings and classroom practice.

Keywords Interaction analysis · Participation · Power · Status · Positioning theory · Technology

Introduction

Computer-supported collaborative learning (CSCL) environments are broadly defined as the use of technology in either a face-to-face (e.g., shared computer) or online (e.g., discussion board) context to support and enhance learning activities through collaboration or the sharing and distribution of knowledge through interacting with others (Arvaja et al. 2008; Barros-Castro et al. 2014; Dillenbourg 1999; Lipponen 2001). It is assumed that collaboration or groupwork, as opposed to cooperation, provides an opportunity for each member of the group to contribute and engage in a coordinated effort to solve a shared problem or attend to meeting shared goals (Arvaja et al. 2008; Cohen and Lotan 2014; Webb et al. 2006).

Yet, we must consider the manner in which power and intellectual authority are negotiated among group members working within CSCL environments, as both subtle and overt issues may impact student participation and opportunities to learn. For example, Langer-Osuna (2016) and Wood and Kalinec (2012) noted lowered opportunities to learn and engage in mathematical sense-making for students who do not have a voice and are subjected to group members' instructions. Thus, peer collaboration in CSCL settings is not a fail-safe strategy (Azevedo et al. 2004; Chavez and Romero 2012; Sinha et al. 2015; Winters and Alexander 2011). For instance, Winters and Alexander (Winters and Alexander 2011) reported that students in their study experienced varying degrees of success, even when the given tasks and instructions explicitly encouraged collaboration within a computer learning environment. Gains in student learning were more often experienced among pairs of students who negotiated a shared understanding and engaged in active processing strategies such as reading notes as opposed to engaging in off-task behaviors and questioning their partner for procedural understanding. This example illustrates how "[i]n CSCL settings, the extent to which collaboration is productive in ways that lead to conceptual understanding depends on high quality engagement in shared activity" (Sinha et al. 2015, p. 274).

Emergent CSCL research converges on the point that group practices necessary "for productive collaborative learning are an important part of the learning process" (Law et al. 2017, p. 6). Law et al. (2017) made a call for "lively and productive debates on these critical issues to advance the field of CSCL," including "analysis of social interaction and collaboration of dyad and group practices" that can "systematically inform the design, testing, and refinement of CSCL environments and practices" (p. 6). And yet, issues of power and status—which are central to these ongoing conversations in the field—remain under-theorized and understudied in extant CSCL scholarship (Barron 2003; Dillenbourg et al. 2009; Prinsen et al. 2007; Sinha et al. 2015). Motivated by research that suggests issues of status (i.e., high/low versus equal; Cohen and Lotan 1995) impacts participation, group interactions (e.g., Bento and Schuster 2003), and opportunities to learn (e.g., Barron 2003; Shaw 2013; Wang and Lin 2007), this study attends to these urgent issues by investigating how issues of power and intellectual authority are negotiated and maintained among students around shared technologies in CSCL learning environments.

Literature review

In the current CSCL landscape, the learning environment and technologies employed are numerous and varied, as well as how collaboration and social interaction are defined and conceptualized (Law et al. 2017), Complementary yet disparate interdisciplinary scholarship reflects a “rich tapestry” of “methodological and epistemic diversity in the CSCL research community” (Law et al. 2017, p. 1). One unintended consequence of these strengths in scholarly diversity is ambiguity on effective design of the CSCL environments, including the learning technology, the learning task, and facilitator practices that support learner engagement in group practices.

Within this context, benefits of CSCL environments converge on the exchange of positive and supportive comments (Janssen et al. 2007), responsiveness to and demonstration of respect of group member’s ideas (Sinha et al. 2015; Tissenbaum et al. 2017), higher-level cognitive problem-solving strategies and shared content knowledge building (Arnseth and Krange 2016; Barros-Castro et al. 2014; Hakkarainen and Palonen 2003; Kapur and Kinzer 2007; Salovaara 2005; Shell et al. 2005), gains in learning performance (Salomon and Globerson 1989; Shaw 2013), and a perception of collaboration as positive (Barros-Castro et al. 2014; Shell et al. 2005). For example, Sinha et al. (Sinha et al. 2015) examined the quality of engagement of ten collaborative groups as they utilized simulations, modeling tools, and hypermedia in a unit on aquatic ecosystems. Based on their analysis, group members who were highly engaged exhibited on-task behavior, populated a shared workspace in which the majority of members contributed and respected one another’s ideas, and made connections to content and unit objectives.

Despite these benefits, a variety of problems have been documented in extant literature when CSCL was adopted, including perpetuation of misconceptions in content knowledge (Barros-Castro et al. 2014; Janssen et al. 2007), negative judgments and comments toward others (Janssen et al. 2007), and short discussion threads in online work (Lipponen et al. 2003). Continuing with the study by Sinha et al. (Sinha et al. 2015), some collaborative groups exhibited low levels of engagement, off-task behaviors, completing tasks individually, ignoring each other’s ideas, and consistent use of “I” language. Similar discrepancies in student participation and engagement in computer-based, cooperative small group settings have also been documented by others (Baker et al. 2012; Kapur and Kinzer 2007; Salovaara 2005; Winters and Alexander 2011).

These dilemmas are not unique to CSCL settings, as issues of status and power are well-documented mediators of effective collaborative learning designs (Barron 2003; Chavez and Romero 2012; Cohen and Lotan 1995; Salomon and Globerson 1989). Assumed roles within the group may be dictated by status characteristics or “attributes on which people differ (e.g., gender, computer expertise) and for which there are widely held beliefs in the culture associating greater social worthiness and competence with one category of the attribute (e.g., men, computer expert) than another (e.g., women, computer novice)” (Correll and Ridgeway 2003, p. 32). These roles may be further delineated by how students perceive their academic competence in relation to other group members; in other words, how students position themselves and one another may be based on perceived differences in ability in a particular subject area or skill (Cohen and Lotan 1995; Correll and Ridgeway 2003; Salomon and Globerson 1989).

Status problems and imbalances of power are frequently evidenced by dominating interaction patterns and likely to impede group productivity and student performance (Cohen 1994).

In addition, students may take on and maintain certain roles and become characters within particular hierarchical structures (Correll and Ridgeway 2003; Salomon and Globerson 1989). For instance, Salomon and Globerson (1989) discussed the "free rider" effect in which a group member is known for her or his competence and eventually takes on the majority of work as other members feel less able and put forth less effort. Another possibility includes the effect of one or two members expending more effort due to interest in a task or distrust in the abilities of others, and thus not pooling the efforts of every group member. These behaviors have the potential to become self-fulfilling prophecies, which are difficult to eradicate.

Although the goal of CSCL environments is to promote student learning through collaboration, these environments may suffer similar problems with status and power as those documented in similar technology settings (Hakkarainen and Palonen 2003; Janssen et al. 2007; Kapur and Kinzer 2007; Prinsen et al. 2007; White 2006). For example, Kapur and Kinzer (2007) examined student participation in solving ill-structured problems in a text-only chat format. They concluded that solving problems that are not clearly defined and allow for multiple entry points and non-routine solutions, led to inequitable groups in which one or two members dominated the discussion and problem-solving space. This inequitable participation pattern occurred early in the task and was maintained until completion of the task. This affected the quality of the discussion as it became one-sided and more difficult for all members to make a meaningful contribution.

These examples document our limited understanding as a field "of the quality of engagement fostered in these contexts, in part due to the narrowness of engagement measures" (Sinha et al. 2015, p. 273). We agree with Lipponen et al. (2003) that we need more research that investigates potential relationships between classroom technological usage and student participation and participation and engagement (or lack thereof) among individuals in collaborative groups (see Janssen et al. 2007; White 2006 for exceptions), as researchers were more likely to consider the mediating effect of other variables such as problem type (Kapur and Kinzer 2007), group size (Shaw 2013), self-efficacy (Wang and Lin 2007), and assignment of group roles (Strijbos et al. 2007). Considering this background, we pursued the following research question:

> *How and to what extent do interactions around technology embody negotiations of power and status in computer-supported collaborative learning contexts?*

We used positioning theory to conceptualize our investigations of potential relationships between students' interactions across two partner pairs working with technology in an all-female cryptography summer camp and their negotiated positions of power and status. Few studies have used positioning theory as a way to understand educational settings, and none have applied it in a CSCL environment. We framed our study using positioning theory because it has the analytic potential for assessing team process and group learning in CSCL environments, thereby allowing our study to make progress on broader questions in the field about what gets in the way of student participation in CSCL settings (Paulus et al. 2009). Q7

Conceptual framework

In positioning theory, the general metaphors of *positions* and *positioning* were introduced as a way to locate and observe individuals within conversations in which storylines are jointly produced (Davies and Harré 1990). These concepts differ from the notion of roles, which is a static and ritualistic concept where an individual's role is understood in relation to another's role such as daughter/father, student/teacher, and player/coach. Within positioning theory, the "focus is on the way in which the discursive practices constitute the speakers and hearers in certain ways and yet at the same time is a resource through which speakers and hearers can negotiate new positions" (Davies and Harré 1990, p. 61). In other words, within every social interaction or episode, an individual is positioning oneself while simultaneously positioning another individual. It is a reciprocal relationship in which the speech acts of individual's words afford and/or hinder individual's communicative acts and positions within any social episode and negotiated storylines (Davies and Harré 1990). In this study, we expand this view of discursive practices to include gestures, body positions, and utilization of artifacts; these nonverbal cues and tangible resources may also contribute to understanding the manner in which individuals position self and others (Herbel-Eisenmann et al. 2015; Leander 2002; Wohlwend 2009). Drawing upon the scholarship of Leander (Leander 2002), we refer to the technological devices in this study as *positioning artifacts,* which we define as instruments that individuals make use of to establish and/or maintain unequal positions of power.

As such, an individual becomes positioned as a particular kind of person within various social interactions (Anderson 2009; Harré et al. 2009). Hence, the individual "sees the world from the vantage point of that position" (Davies and Harré 1990, p. 46). For example, Tait-McCutcheon and Loveridge (2016) noted how one teacher in their study positioned herself as possessing the right to lead students to correct answers through maintaining control of mathematics instruction while simultaneously positioning her students as possessing the duty to follow instructions and mimic mathematical actions. Students accepted this position and mutually positioned this teacher as the dominant participant in the mathematics classroom, thereby, as concluded by Tait-McCutcheon and Loveridge, limiting the opportunities for these students to participate and engage actively with the mathematics and with others.

As this study illustrated, positioning theory uncovers the manner in which communicative acts "can denigrate one's position in the world or enhance it, making one feel powerful or powerless" (Johnston and Kerper 1996, p. 9). In the study above, the teacher was positioned as powerful and in a position of high-status, while the students were mutually positioned as powerless and in a position of low-status (Cohen 1994; Harré et al. 2009). As stated by Wagner and Herbel-Eisenmann (Wagner and Herbel-Eisenmann 2009),

> The cultural capital that serves a student well in [their] communities outside of school may not allow [them] to resist teacher-enacted storylines in a classroom. Furthermore, a teacher may enact a storyline that invites or discourages student initiative and thus influence the willingness of a student to risk initiating a new storyline. (p. 5)

Within the local context of a classroom, peers also mutually position one another within positions of high- and low-status (Bishop 2012; Davies and Hunt 1994). For instance, Bishop (2012) noted how one student was jointly positioned as mathematically inferior, or the "dumb one," while the other was jointly positioned as the mathematically superior, or the "smart one."

Positioning theory may also expose the way an individual uses her or his power (or lack thereof) to position one's self as holding high- or low-status (e.g., Davies and Hunt 1994; Esmonde 2009; Esmonde and Langer-Osuna 2013; Ritchie 2002; West-Olatunji et al. 2007; Yoon 2008). For example, Yoon (2008) examined regular classroom teachers' approaches to working with multilingual students, particularly, the manner in which the teachers offered or limited opportunities for the students to participate as active members of the classroom. Results highlighted how teachers' pedagogical approaches and social interactions with multilingual students were based on the teachers' positionings in relation to their general beliefs and understandings regarding multilingual students. These acts of pedagogical approaches and social interactions positioned the students in their respective classes as either powerful and strong, or powerless and weak.

Methods

Research setting

Our study is broadly situated in an all-female one-week Science, Technology, Engineering, and Mathematics (STEM) summer camp for rising high school freshman and sophomores (n = 22) at a university located within the southeastern region of the United States. The camp aimed to combat the gender disparity of those who pursue and maintain a STEM career (National Q8 Science Foundation 2015) through boosting mathematics skills and increasing confidence and awareness of career opportunities in STEM. Camp participants generally come from within the state or neighboring states. In general, students do not know one another prior to the camp. The camp offered need-based scholarships, with over 70% of students receiving half- or full-tuition scholarships.

Camp participants engaged in a variety of daily sessions, including robotics, bioengineering, automotive engineering, and dance. Our study was conducted during campers' mathematics sessions, which leveraged technological tools to foster pair engagement and student understanding in solving complex cryptography-focused tasks. By way of example, campers explored the process of enciphering and deciphering messages using various cryptosystems, including substitution ciphers such as the Caesar cipher as well as the Rivest et al. (RSA) cryptosystem (1978), in order to support their understanding of the mathematical processes used to keep private information secure. Campers worked in partner teams of two on mathematical tasks that required computational tools such as Wolfram Alpha (2016), ciphering applications on laptops, and text messaging applications on iPod Touch handheld devices. The utilization of these tools varied based on the mathematical tasks. Two of the tasks relevant to this study will be discussed below.

Data source and reduction

The primary data source for this study was video recordings of the mathematics sessions. We videotaped each session continuously using five cameras that were positioned to capture partner interactions at every student table, yielding about 25 h of video recordings. We began our analysis with a data reduction. We omitted video footage of work that did not require collaboration, such as listening to the instructor or reflective writing. We also eliminated video footage with inaudible sound. Author A made a content log of the remaining footage (Jordan and Henderson 1995), which included an in vivo summary of events, annotations of partner interactions, and memos regarding verbal and nonverbal communication. As a result, partner interactions from two teams—Jasmine & Becky and Sasha & Lily—emerged as contrast cases meriting further analysis and comparison. Through video reduction, the total length of the video clips analyzed for this study was approximately 34 min for Jasmine and Becky and approximately 13 min for Sasha and Lily. Information about these participants is displayed in Table 1.

Q9 **Table 1** Participant information

Pseudonym	Age	Previous Mathematics Course	What do you like about math?
Jasmine	14	Algebra 1	I love everything about math. I love the calculations and I love that you can find math everywhere around us.
Becky	13	Algebra 1 Honors	Everything.
Lily	14	Mathematics 8	I like problem solving.
Sasha	12	Algebra 1 Honors	It's logical and everything ends up making sense.

Data analysis

We utilized *interaction analysis* methods (Jordan and Henderson 1995) to empirically investigate partner interactions within the emergent contrast cases because of our interest in understanding relationships between camper interactions around shared technologies required for a complex problem-solving task. In Phase 1 of the analysis, the research team viewed videos together silently in two-minute increments. After each 2-min segment, we discussed our observations using evidence of campers' interactions and activities from the video to support our observations. In addition, we discussed our individual and collective preconceived assumptions and subjectivities based on our familiarity with the context and participants (e.g., Yoon 2008) at the conclusion of the first step of the process. These observations and mini-discussions helped the research team co-construct the focus of this study.

Next, each of the video clips was transcribed verbatim in a six-column format including both verbal and nonverbal cues (e.g., body positioning) for each participant pair, as well as for other individuals such as counselors and educators (Ochs 1979). Additionally, Jefferson (Jefferson 1985) transcription notation was utilized to capture the dynamics of the interaction (e.g., overlap in talk) and the characteristics of how the verbal information was delivered (e.g., rising inflection). Verbal and nonverbal behaviors were included, because they, at times, occurred simultaneously and potentially carried varying communicative acts, including varying acts of positioning within multiple storylines (Harré et al. 2009; Moghaddam et al. 2008; Ochs 1979). Inclusion of verbal and nonverbal communication also allowed us to productively analyze interactions around technology through the lens of positioning theory (Herbel-Eisenmann et al. 2015; Ritchie 2002; Yoon 2008). Verbal and nonverbal cues were numbered to indicate actions that occurred at the same time. In addition, time stamps were included to understand how participants sequentially and jointly positioned one another. Refer to Table 11 in the appendix for an example.

Phase 2 of the analysis included positionings at the levels of words and social interactions within thematic episodes or "any sequence of happenings in which human beings engage which has some principle of unity" (Harré and van Langenhove 1999, p. 4; Lemke 2000). The transcriptions were utilized to examine verbal and nonverbal exchanges for first-order and second-order positionings around technological devices (i.e., positioning artifacts); first- and second-order positionings are explained below. This provided a means to understand the focus and intent of the communicative acts around technology as well as the manner in which participants were positioned relative to one another, which at times highlighted issues of power and status (Herbel-Eisenmann et al. 2015; van Langenhove and Harré 1999). Q10

First-order positionings are implied and occur within every social interaction. Those involved in the social interaction agree upon on their negotiated position(s); therefore, everyone agrees upon their rights and duties as a particular kind of person. Second-order positionings occur when an individual seeks to change his or her position. Second-order positionings tend to highlight issues of power and status between or among individuals (Herbel-Eisenmann et al. 2015; Ritchie 2002; van Langenhove and Harré 1995) and may result in a dysfunctional group dynamic and disengagement from the task for some group members (Ritchie 2002). In general, any utterance or action provides evidence of positions of power and status within any episode as some verbal and nonverbal acts are taken up while others are challenged or resisted (van Langenhove and Harré 1999).

Hence, we developed verbal and non-verbal codes specific to first-order (i.e., submissive positioning moves) and second-order positionings (i.e., counter positioning moves). These are noted in Tables 2 and 3. We contend that submissive positioning moves imply acceptance of one's position as a particular kind of person, while counter positioning moves imply not accepting one's position as a particular kind of person. Within this study, counter positioning moves are also associated with moves of dominance and high-status individuals; actions and behaviors to maintain one's position. We applied these codes to each line of transcription, while keeping in mind how verbal and non-verbal acts of communication positioned our participants through sequential meaning-making (Roth 2015; Stahl 2017).

Consider the following as an illustration of our analysis. Unlike excerpts below, here we include codes in ALL CAPS within brackets.

Table 2 Positioning codes

Reference	Submissive Positioning Moves (First-Order)	Counter/Dominant Positioning Moves (Second-Order)
Verbal Acts of Communication		
Hall et al. (2005)	Vocal variability (e.g., animation, tone of voice)	Minimal vocal variability
Hall et al. (2005)	Quiet voice amplitude	Loud voice amplitude
Hall et al. (2005)	Unsuccessful and/or minimal interruptions	Successful and/or more interruptions
Ritchie (2002)	Explicit Agreements (e.g., "Okay, saw on this line here and here." p. 49)	Explicit Disagreements (e.g., "No, we're doing solar panels." p. 42)
Non-verbal Acts of Communication		
Burgoon et al. (1984); Mehrabian (1969)	Low degree of eye contact	High degree of eye contact
Burgoon et al. (1984); Hall et al. (2005)	Distant Proximity	Close Proximity
Cohen and Lotan (2014)	Little to minimal control of artifacts	Control of artifacts
Hall et al. (2005)	Closed body position (e.g., arms and legs crossed, body as shield)	Open body position (e.g., open arms and legs)
Henley (1977)	Smiling	Minimal smiling
Henley (1977); Major and Heslin (1982)	Refrain from touch	Initiate and engage in touch
Keiser and Altman (1976); Mehrabian (1969)	Relaxed seating position (e.g., backwards body lean)	Non-relaxed seating position (e.g., forward body lean; upright)
Leander (2002)	Lower body half directed away	Lower body half directed toward

We acknowledge that numerous studies have examined similar verbal and non-verbal acts of communication with non-significant or inconclusive results. See Hall et al. (2005)

Table 3 Illustration of analysis using positioning codes

	Time (sec.)	Becky	Jasmine
1	5:40	*With body turned forward* [S: BODY DIRECTED AWAY]– *sitting in upright position* [C: NON-RELAXED], *turns head toward Jasmine* [C: OPEN], *eyes directed toward handout* [S: LOW DEGREE OF EYE CONTACT]	*Writing in handout with right hand; iPod in left hand* [C: ACCESS]; *Body turned forward* [S: BODY DIRECTED AWAY] – *back bent in a slumping position* [S: RELAXED]
2	5:42		*Looking up from handout; Turns head toward Jasmine* [C: OPEN] *and attempts to make eye contact* [C: EYE CONTACT] Are you done? [C: MINIMAL VARIABILITY]
3	5:44	*Pivots left arm from head to open palm directed toward the iPod, immediately pulls arm up* [S: CLOSED]; *eyes adverted down* [S: LOW DEGREE OF EYE CONTACT] No. Are you done with that? [C: DISAGREEMENT; MINIMAL VARIABILITY]	*Turns head back toward iPod* [S: CLOSED] *with lower trunk still forward* [S: BODY DIRECTED AWAY]
4	5:49	*Head still directed toward Jasmine* [C: OPEN] *with eyes still adverted down* [S: LOW DEGREE OF EYE CONTACT] *and lower trunk forward* [S: BODY DIRECTED AWAY]	*Continues writing in handout; iPod remains in left hand* No. [C: DISAGREEMENT]
5	5:52	*Turns head forward* [S: CLOSED]; *Flips page in handout*	
6	5:59		*Looks up and toward Becky* [S: OPEN] I'm done. [C: MINIMAL VARIABILITY]
7	6:01	*Reaches out left hand – palm open* [C: OPEN]; *Eyes toward iPod-hand exchange* [S: LOW DEGREE OF EYE CONTACT]	*Reaches across her body to place iPod in Becky's left hand; adverts eyes to iPod-hand exchange* [S: LOW DEGREE OF EYE CONTACT]

S, submissive positioning move; *C*, counter/dominant positioning move. Verbal communication. Non-verbal communication

The case of Becky and Jasmine: Stark power imbalance curtails opportunities to learn

We found evidence in our analysis of interactions between Becky and Jasmine that Jasmine positioned herself as the more powerful, higher-status team member. Her physical control over the shared laptop and iPod denied Becky access to resources essential for task completion. Despite Jasmine's territorial claims and mistreatment, Becky at first did not accept her position as a less powerful team member; she showed motivation and curiosity in completing the task. However, Jasmine's escalating dominance seemed to diminish Becky's will to counter her position of lower status as she became submissive to Jasmine's power moves by the end of the class.

Computer-supported mathematical context: Decipher an encrypted text message

The interactions we analyzed for this case were recorded on Day 4 of the mathematics sessions. The task was to decipher an encrypted text message, which involved completing a multi-step computational process, recording intermediate results accurately on a handout, and sharing the technology resources required for task completion (i.e., iPod, laptop). As such, it was the lead instructors' intent for pairs of students to work collaboratively on completing the task as opposed to working cooperatively or in parallel with one another. To begin, each partner team was sent RSA ciphertext as a text message, received on a "shared" iPod. Each partner team was challenged with deciphering the message; this means they were to convert the ciphertext into plaintext (in English). To do this, it was expected that each student copy the string of numbers contained in the text message onto a handout. As illustrated in the appendix, each number in the string was then multiplied by another number S (the private, or secret, key) modulo N (part of the public key).

The instructors agreed that requiring campers to complete this process by hand was inefficient and atypical for professionals who do this work. Determining a single letter of plaintext involves multiplying two 2-digit or 3-digit numbers and then finding the remainder upon division by another 2-digit number. Since the message string was 15–20 letters long, completing the computations by hand would mean repeating this process on paper at least 15 times. Consequently, each team used Wolfram|Alpha via a shared laptop for these computations. The product $\#*S \bmod N$ was then recorded on the handout for each letter in the string. This product is a number between 0 and 25, which was then converted to a letter A-Z depending on its value. Repeating this for each number in the ciphertext allowed the team to recover the message in text.

Jasmine claimed ownership of shared technology and positioned herself as higher status

Our analysis supports the claim that Jasmine asserted physical ownership over shared technology resources, which positioned her as a more powerful, higher-status team member. We made this conclusion based on Jasmine's physical actions with and positioning of the materials within their shared workspace, as well as non-verbal acts of communication such as instances of close proximity (e.g., reaching across Becky) and little to no smiling. Initially, the iPod was located in the middle of the circular table, and the laptop was situated between Becky (sitting on the right) and Jasmine (sitting on the left) such that the screen was visible to both of them. Immediately after the lead instructor launched the task and while Becky was busy searching through her bag for her task handout, Jasmine quickly reached for the laptop and oriented it in her direction despite already being able to see the screen and not having a need to use it until later on in the task. In other words, Jasmine took this opportunity to assert ownership of the laptop. Moreover, this action reduced Becky's ability to see the laptop screen from her seat.

A similar assertion of ownership occurred with the iPod. When Jasmine needed the iPod, she grabbed it from the center of the table, used it to find the encrypted message, and placed it on the base of the laptop that was still oriented in her direction instead of returning it to the center of the table (see Fig. 1). Becky, with her back toward Jasmine – a submissive positioning move - gave the appearance of busyness at this time by thumbing through her handouts and drinking water from her canteen. It took her about 1.25 min to consume a small amount of water while Jasmine finished using the iPod (see Fig. 1). Also, as seen in Fig. 1, Jasmine has her body positioned away from Becky, which is a submissive positioning move. In this case, it implies acceptance of Becky's

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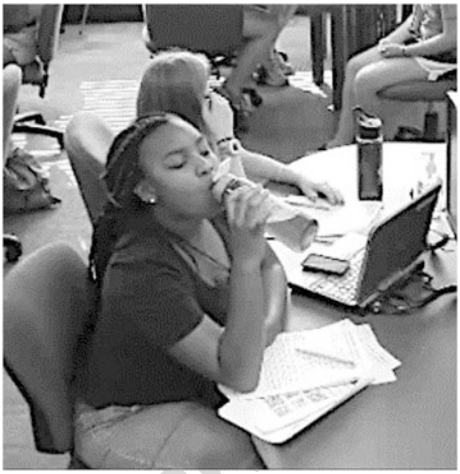

Fig. 1 Jasmine controls technology. Becky acts busy

positioning of herself as removed from the task and not in control of the technological devices. In other words, Jasmine did not make an effort to shift Becky's positioning as being a passive member of the pair by inviting her to use the devices.

These interactions support the conclusion that Jasmine's initial assertions of power over the laptop and iPod positioned her as the controller of the essential technology for this task; thus, she was in a position of power and in control of the intellectual space. In addition to dealing with the difficulty created by the materials being placed out of her reach, Becky also faced the challenge of being positioned to ask Jasmine for permission to use essential technology tools that no longer belonged to the collective. Furthermore, at this point, we interpreted Becky's preoccupation with "acting busy" as not only acceptance of Jasmine's positioning of power, but also as a coping strategy for dealing with Jasmine's positioning moves of power and status (Cohen 1994). Becky temporarily avoided a need to interact with Jasmine and with the shared technology resources by disconnecting from the cryptography challenge, yielding herself to a positioning of lower status.

Becky persisted with the task despite denied access and resisted Jasmine's assumed power

The deciphering task required accurately recording a string of numbers from an iPod, performing computations on the laptop, and organizing the results on paper. Jasmine's early control over team materials and positioning of higher status resulted in her working far ahead of Becky. Becky could not make progress on the task because she could not get her hands on essential technology resources from the get-go.

Nevertheless, Becky persisted, showing motivation and curiosity in the task—characteristics not uncommon for low-status students (Cohen 1994)—evidenced by repeated attempts to complete the task and figure out what was going on. For example, we observed Becky craning her neck to see what was on the iPod screen. We also observed Becky orienting her head and body forward, toward Jasmine, to glance at Jasmine's handout, to then copy numerical information to her own handout. This is the first instance in which Becky rejected her position of lower status through non-verbal communication.

Becky eventually gained access to the iPod but only after Jasmine declared, “I’m done.” Jasmine never shared the laptop with Becky, even when she needed Becky’s help formatting an exponential expression in Wolfram|Alpha (see Table 4). In fact, this is the only time Becky used the laptop—to show Jasmine the location of the two keys needed to type the karat key (^).

The interaction featured in this excerpt also revealed some evidence that Becky was resistant to Jasmine’s assumed control over shared resources. Jasmine asked Becky for help four times before getting a response from Becky (Lines 1–7). It could be argued that Becky simply did not hear Jasmine, especially since this was the pair’s first verbal interaction. On the other hand, given their physical proximity, it is likely that Becky heard Jasmine’s repeated requests; it takes effort to avoid turning toward a person who speaks to you directly. As noted in the short excerpt, Becky glanced in the direction of the laptop, but chose to continue with her task as opposed to answering Jasmine (Line 3). This suggests that Becky was pushing back against Jasmine’s assumed position of power. In addition, Jasmine seemed to relinquish her position of higher status for a *brief* moment as she not only asked for help from Becky, but avoided making eye contact (e.g., Lines 1, 5, & 8).

Jasmine positions Becky as intellectually inferior

The examples thus far draw attention to some of the negative impacts of Jasmine’s assertions of power. They raise questions about why she denied Becky access to shared technology resources in the first place. One reason that emerged from our analysis is that Jasmine did not view Becky as an intellectual equal, because Jasmine relied exclusively

Q13/Q14/Q15 **Table 4**

	Time	Becky	Jasmine
1	6:43	*Writing numbers in handout; lower body forward*	*Looking towards laptop with lower body forward and back bent over in slumping position* How do you do:::::
2	6:53		*Right elbow on table with hand on head* How do you ↓do (.) that ↑up arrow [karat key]?
3	6:56	*Glances in direction of laptop, then continues with task*	
4	6:58	*Continues with task*	*Pushing buttons on keyboard*
5	7:06		*Looking at laptop; Right elbow still on table with hand on head* Hey (0.4) do you know how to do that up ↑arrow?
6	7:16	*Slightly turns body and lays down iPod* Huh::?	
7	7:20		*Looking toward laptop* How do you do that up arrow?
8	7:21	That ↓one [Shift]. *Points to key.*	*Looking toward laptop*
9	7:23	And that ↓one [6]. *Points to another key.*	
10	7:25	*Shows again using two fingers.*	*Continues looking toward laptop* Oh::::, shift.
11	7:28		Okay (.) ↑good.
12	7:30	*Removes hand from keyboard and picks up iPod.*	*Places both hands on keyboard and turns head away toward handout*

Verbal communication. *Non-verbal communication* on course instructors for help when she struggled with mathematical aspects of the deciphering task. She did not ask Becky for mathematical help, although she did ask Becky lower-level questions about non-mathematical procedures, such as clarifying how to type the karat key on the computer (Table 4).

To elaborate on one such instance, Jasmine requested help from the lead instructor: "I typed in 697 and I got too large a number." Jasmine intuitively knew that something was wrong because she did not get a number between 0 and 25, which would have aligned with one of the letters of the English alphabet (numbered 0 to 25). Becky, with eyes averted and focused downward toward the laptop, sat silent as Jasmine engaged in a problem-solving conversation with an instructor. She was unable to meaningfully contribute to or join this conversation since she had just gotten the iPod from Jasmine. Indeed, Becky was just beginning to work with the encrypted number string and had not yet reached the point where she would get a number between 0 and 25. In this instance, Becky was again positioned as the individual with lower status. As another instance, Jasmine asked for mathematical help from a doctoral student volunteering within the class. Again, we observed Becky being a silent member, but unlike the first example, she disengaged from the conversation as she turned back to completing her work in Line 5. In other words, Becky accepted her position of lower status as she distanced herself from Jasmine by turning her head away from the laptop.

Unfortunately, Jasmine continued to position Becky as lower status and as intellectual inferior. In the following example, Jasmine positioned herself as a competent academic providing directives regarding completion of the task. This instance occurred approximately six minutes following the episode in Table 4. Becky turned her face toward Jasmine and quietly indicated she needed the laptop to move forward when she reached the computationally intensive part in the task. Jasmine responded to Becky's stated need to use the laptop with advice on how to proceed, including directions on how to type in the second row of numbers into the laptop and instructions for writing down the corresponding letter in the third row. Jasmine then turned her attention back to the laptop and continued with her work. Jasmine's response completely ignored Becky's need to use the laptop while also communicating unsolicited advice about the deciphering task that Becky did not need or ask for. It is unclear why Jasmine thought Becky needed these directions. It is also unclear why Jasmine gave Becky explicit directions about using the laptop since she ignored Becky's request and continued blocking access to the laptop from Becky for the remainder of the task. As a collective, these observations confirmed Jasmine's perspective and position of power as well as Jasmine's positioning of Becky as intellectually inferior, at least within the context of this mathematical task.

Jasmine escalates dominance with physical positioning

We found evidence that Jasmine escalated her dominant positioning as intellectually superior with physical invasions of Becky's personal space. For instance, Becky realized that some of her computations were incorrect (see Table 5). Before she had the opportunity to look for and correct the error for herself, Jasmine told Becky to mark the mistake on her paper for later review while pointing to the mistake.

Jasmine's physical proximity as noted in Lines 4 and 11 of Table 5 further positioned her assumed dominance, evidenced by her leaning in to Becky and touching her paper (see Fig. 2). Becky accepted this physical positioning of dominance through closed off behaviors - avoiding eye contact and keeping her elbow up as a shield. When speaking to Jasmine, Becky kept her body and head position forward.

Table 5

	Time	Becky	Jasmine
1	19:05	*Erasing information from handout; Body forward – sitting upright* I think I ↑messed up some (.) place.	
2	19:11	*Left elbow on table and left hand on forehead; looking toward handout*	*Stops typing; Keeps looking toward laptop* Put a line over the number you think you messed up ↑on (.) and I'll check over them in a minute.
3	19:16		*Pushes hair behind right ear and looks at handout, then adverts eyes to Becky's handout*
4	19:22		That's two. *Reaches across Becky and points to specific place in handout. Pulls back* Wait. Yeah (.) that's two.
5	19:26	*Moves left hand from forehead* Yeah, I was rewriting that. *Erases information from handout*	*Looks toward Becky's handout*
6	19:30		What are you doing? *Still looking at Becky's handout*
7	19:32	*Stops erasing* They are all (.) out of place. *Places elbow on table and left hand on forehead; looks at iPod*	*Adverts eyes toward Becky.*
8	19:35		Are mine (0.2) out of ↓place? *Eyes toward her handout*
9	19:38	No. *Writing in handout*	*Adverts eyes toward Becky's handout*
10	19:45	*Stops writing; Left elbow on table and left hand on forehead; looking toward handout*	That's 1146. *Reaching across Becky and point to specific place in handout; eyes looking toward Becky's handout*
11	19:52	*Eyes looking back and forth from iPod to her handout*	*Taps pencil up and down in Becky's handout*
12	19:55	I'm not even ↑on that number.	*Leans back*

Jasmine's physical assertions of power continued, such as when the lead instructor challenged the class to decipher one more message near the end of the session. This challenge created a need for Jasmine to use the iPod again. Jasmine unabashedly took the iPod out of Becky's hands not once—but twice—without Becky's consent (Table 6, Lines 2 & 22). Becky

Fig. 2 Invasion of Becky's intellectual space

Table 6

	Time	Becky	Jasmine
1	28:40	*Pushes the power button of iPod (positioned in front of body on table), then touches the screen; head directed toward iPod*	
2	28:42	*Scrolling through iPod; keeps head down toward handout*	O::kay. *Turns head toward Becky; averts eyes down; grabs iPod from Becky and cups in both hands; turns head forward toward iPod*
3	28:58	*Erases information from handout.*	*Copying numbers from iPod to handout.*
4	29:04	*Extends neck to look at Jasmine's handout; continues erasing.*	
5	29:08	*Continues moving head back and forth between Jasmine's handout and her own – writing in handout*	*Holds iPod with left hand down at the base; continues writing in handout*
6	30:00	*Continues moving head back and forth between iPod and her handout – writing in handout*	*Lays iPod upright between the laptop screen and the keyboard; starts typing in numbers from handout - head moving back and forth be tween laptop and handout*
6	30:21	*Picks up iPod and transfers numbers to handout.*	
Break in Excerpt.			
21	32:52	*Writing in handout.*	*Looking at laptop screen.*
22	33:01		*Reaches across Becky and grabs iPod from her hands; eyes directed down toward iPod*
23	33:03	*Scratches forehead; keeps head down*	*Touches iPod screen; writes in handout.*
24	33:07	*Writes in handout – without looking toward Jasmine.*	
25	33:26		*Lays iPod down out of reach of Becky.*

continued to work on the task by copying down numbers from Jasmine's handout to her own. She did not contest Jasmine's physical assumption of control of the iPod. By Line 24, Becky stopped copying information from Jasmine's handout to her own. From that point forward she wrote down information in her handout without the use of the iPod or laptop.

Jasmine positioned Becky as an incompetent, inferior team member as opposed to an equal peer with the ability to make intellectual contributions to a collaborative, complex task. Our analysis suggests that Jasmine initially positioned herself as the dominant team member by gaining and maintaining control over the technology. She escalated her dominance over Becky using brazen invasions of Becky's personal space. To secure her superior position, she sought mathematical support from others, not Becky, in the learning environment. Despite Jasmine's mistreatment, Becky appeared to resist Jasmine's positioning of power through persistence with the task regardless of lacking control of necessary technological devices. Yet, as the pair continued to work in parallel on a task that was meant to elicit collaboration through the use of shared technologies, Becky's attempts to resist Jasmine's positioning as the dominant member were unsuccessful.

The case of lily and Sasha: Subtle power imbalance has ambiguous effects on outcomes

Our analysis of the interactions between Lily and Sasha revealed positive engagement in acts of collaborative problem solving that were oriented around the team laptop, which was used as a joint thinking tool. However, these acts were not devoid of subtle status negotiations. In this case, Sasha positioned herself as team captain and Lily as her secretary and scribe, which Lily accepted as a position. Although the Team Captain/Scribe relationship may suggest that Sasha solved the problem and explained the result to Lily, our close analysis uncovered a more subtle interaction. We observed Lily also countering this position of lower status as contributing to the mathematical task in the role of questioner.

Computer-supported mathematical context: Crack a Caesar cipher

The interactions we analyzed for this case were recorded on Day 2 of the mathematics sessions. The task for Day 2 was to use a Caesar cipher to encipher and decipher several messages. Teams were asked to decipher each piece of ciphertext, meaning convert it from a meaningless string of letters A-Z to one that has identifiable meaning in the English language. Each team was expected to determine the key (a letter A-Z), which would allow for this conversion. Specifically, students are expected to make educated guesses based on details such as spacing and letter frequency and then experiment with potential keys using an online tool accessed via laptop. The solution was found when the key resulted in a message legible in English. Hence, this task required the use of a laptop and an online tool—"Crack a Caesar Cipher" (Crypto Club Project and Eduweb n.d.)—to decipher secret messages.

Sasha and lily used laptop as joint thinking tool

Our analysis suggests that Lily and Sasha positioned one another within a collaborative problem-solving space during their work on the Caesar cipher task, evidenced in part by their consistent use of their shared laptop as a joint thinking tool. From the start, the laptop was situated between Lily (sitting on the left) and Sasha (sitting on the right). It remained oriented so that both females could see the screen throughout the analyzed video footage (see Figs. 3, 4, Q16 and 5). Moreover, Sasha and Lily's interactions were also oriented toward a central workspace in relation to the laptop screen. As they worked together on the Caesar Cipher, they were observed pointing to the screen at different moments as well as sharing ideas and feedback out loud. We found that Lily and Sasha appeared to appreciate one another's contributions in cracking a coded message.

Fig. 3 Shared intellectual space of Lily and Sasha

Fig. 4 Lily as secretary and Sasha as team captain

For example, as demonstrated in Table 7, Lily and Sasha's interactions included acts of happiness and gratitude (Table 7, Lines 11–13), as well as respectful turn taking when narrating their way through the task. Taken together, the evidence suggests that Sasha and Lily used the laptop as a joint thinking tool in context of the collaborative problem-solving space they organized around the team laptop. Yet, as shown below, their centrally-oriented, consistently friendly workspace was not void of power negotiations and subtle positionings of dominance.

Sasha became team captain and lily became her secretary

Although Lily and Sasha collaborated on the Caesar cipher within an inviting, shared intellectual space, we found evidence of Sasha positioning herself as team captain. As verified in Tables 7 and 8, Sasha maintained primary control of the laptop through nonverbal communicative acts with Lily, namely being the only one to input information into the laptop for their team. For example, in Table 7, Sasha is noted as typing on the keyboard and moving the mouse. In return, it seemed as if Lily was neither accepting nor countering Sasha's position of higher status. She never asked Sasha for access to the laptop, but she also never positioned her body away from Sasha. As an example, in Table 7, Lily is noted as leaning forward and touching the laptop screen with her pencil eraser as opposed to turning away from the collaborative intellectual learning space (Line 6).

Positioning herself within the participatory role of team captain (Cohen 1994) facilitated Sasha's management of the intellectual workspace as well, such as by privileging her own ideas over Lily's when deciphering messages. For example, we observed this first within the first minute of our analysis, when Lily suggests trying the letter R within the ciphered text. Yet Sasha disregarded this in place of her own idea that Q is the appropriate letter – "I want to move the Q." Sasha accepted this initial move of dominance as she replied with "oh." We observed this again in Table 7 (Line 7) when Lily suggested changing the C to S in the Caesar cipher. Before she could explain her idea fully, Sasha successfully interrupted Lily's think-aloud in favor of the change she preferred (Table 7, Line 7). Note too that this change was initiated by Lily in Line 1 when she voiced concern regarding the position of the letter C in the deciphering program. Hence, Sasha's acts of communication are directed toward

RSA Creating Keys (Group Number)

1. Choose two prime numbers *p* and *q:* p = _______ q = _______
2. Calculate the following: n = _____ * ______ = ____________
   p q

   z = _____ * ______ = ____________
   p - 1 q – 1
3. Find *e* relatively prime to *z:* e = _______

   Then find e^{-1} mod z: d = _______
4. Now fill in your keys: **Public Key** (n, e) = (_____, _____)
   Private Key or d = _______
5. Check your calculations: ______* _____ mod ______ = 1
   d e z

Deciphering using RSA - to convert ciphertext sent to you to plaintext

1. Write #s in message sent to you.
2. Write your n and d. n = _________ d = ___________
3. For each # of message, compute $\#^d$ mod n.
4. Write letter associated with $\#^d$ mod n in chart.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

#							
$\#^d$ mod n							
Associated letter							

Fig. 5 Day 4 task

maintaining her role as team captain. Even further, this is evidenced below in Table 9 (Lines 7–8), as Sasha did not accept Lily's suggestion but wanted to "test" or confirm this suggestion on her own.

The interactions featured in Table 8 corroborate this claim, offering evidence of Sasha negotiating her positioning of power by instructing Lily to write down letters from the screen—as if Lily were her secretary—while Sasha continued her focus on the intellectual work of deciphering a message (Line 7).

Lily appeared to accept this positioning of secretary, as we found no evidence of pushback from Lily in our analysis. This is supported by the fact that she acted as the team scribe by writing down team responses on a collective handout without being directed to do so by Sasha

Table 7

	Time	Lily	Sasha
1	6:27	Aren't we ↑suppo::sed (.) to take like C (0.3) and ↑put it up there? *Points to laptop screen with pencil eraser. Eyes directed toward laptop screen.*	*Looking toward screen.*
2	6:29		Okay.
3	6:30	So like (.) it wouldn't make sense. *Removes pencil eraser from screen.*	*Places hands on keyboard.*
4	6:33	*Still looking towards screen.*	O:::kay. It would be::::: *Begins typing.*
5	6:36		*Stops typing and points to screen with right index finger.* So (0.2) if I'm changing it from…↑Y is S.
6	6:42	*Leans forward and points to screen with pencil eraser.*	
7	6:48	If you change the C to S [then] *Removes pencil eraser from screen and points to handout and then back to screen. Averting eyes back and forth.*	[I need] to change that. ↑That (.) needs to be changed. *Moves right hand from screen. Still looking toward screen*
8	6:52	So it will [be]	[↑Okay], so let me cha::nge *Moves mouse.*
9	6:56	So the key is not right. *Removes pencil eraser from screen.*	
10	6:58	*Leans back in chair.*	Yea::h. This (0.4) this needs to go wa:::::y over (0.8) right (.) there. *Continues moving mouse.*
11	7:02	*Leans forward in chair.*	↑Thank you, that… *Typing on keyboard.*
12	7:04	*Smiling and laughing. Still looking toward screen.*	*Smiling and laughing. Still looking toward screen.*
13	7:08		Appreciate ↑ya. *Moves right hand back and forth as if waving hello.*

Table 8

	Time	Lily	Sasha
1	7:51	*Looking toward direction of laptop screen*	I think it's (0.6) A (0.4) ↓and *Leans forward and types on laptop.*
2	8:03		Thirteen. *Moves mouse*
3	8:04		What ↑the?! I'll do it ↓again. *Scrunches face up*
4	8:17		Eight. *Types on computer.*
5	8:22		C. °That's not right.° It should be H, K, I. *Hits backspace 3 times.*
6	8:33	*Places left hand on cheek*	Here (0.3) I'm going to write it down. *Picks up pencil. Writes on a sheet of paper*
7	8:37	*Removes hand from cheek. Leans back in seat. Still looking toward laptop screen*	*Stops writing. Drops pencil. Moves mouse.* If you could write down what I, A, S, C (0.2) and so on. S.
8	8:48	*Writes in handout*	°Two. Three. Four. Five. Six. Seven. Eight.°
9	8:57		So (0.2) 16. Let me try that one now. *Moves mouse. Types on keyboard.*

Table 9

	Time	Lily	Sasha
1	10:36		*Repositions herself in her seat.*
2	10:37	*Picks up shared handout from table.* Alright. I'll write it.	*Turns head toward Lily*
3	10:40	*Writes in handout. Moving eyes back and forth between laptop screen and handout*	*Sits idle. Eyes directed around the table – not toward handout or Lily*
4	10:57	*Stops writing. Moves left hand to mouth.*	*Leans over toward Lily. Looks toward the handout.* O::kay.
5	11:03	*Moves left hand to forehead. Looks toward laptop screen.*	*Places left hand on chin. Looks toward laptop screen.*
6	11:08	*Writes in handout.*	
7	11:21	*Stops writing. Looks toward laptop screen.* I think (.) A and I are the same thing.	
8	11:25		*Picks up pencil from table. Writes on a sheet of paper.* So, let me…

(see Table 9). Likewise, Sasha continued positioning herself within a position of higher status as she did not oppose or deny Lily's effort to write responses into the handout; nor did she offer to take on this position of lower status. Instead, she approved Lily's work once finished (Line 4). In addition, we observed instances later in the video clip (e.g., at 11:33) of Lily accepting her position of secretary, while simultaneously positioning Sasha as team captain as she would read letters from the handout for Sasha to enter into the laptop.

We further claim that Sasha positioned herself in the higher status role of team captain, evidenced in part by her consistent use of "I" language. In so doing, Sasha positioned herself singularly as the one who moved the pair forward with the Caesar cipher. Phrases like "I'll do it again" (Table 8, Line 3) or "Let me try that one now" (Table 8, Line 9) or "I need to change that" (Table 7, Line 7) show continued evidence of Sasha's positioning as team captain and of her subtle control of the joint thinking tool. On the other hand, Lily tended to use "we" – "Aren't we supposed to take like C and put it up there?" (Table 7, Line 1) or "you" – "If you change the C to S" (Table 7, Line 7). The latter is an indication of accepting Sasha's position as team captain, particularly as the one with access and control of the technological device.

Lily counters her position of lower status

Lily also positioned herself as questioner (Herrenkohl 2006) in addition to, and simultaneously as, her position as secretary. As an onlooker to Sasha's control of the input, Lily asked Sasha a steady stream of questions, or comments that functioned as questions, which kept the team moving forward productively with the task. These questions were framed such that Lily questioned Sasha's input into the laptop as opposed to asking about how to decipher the message. For example, within the first two minutes of the analysis, Lily challenged Sasha's decision that the letter A was enciphered as the letter T by asking, "Are you sure?" In other words, Lily was not positioning Sasha as the "expert" who could provide answers, but challenging or countering Sasha's position as team captain. In some instances, as noted above, Sasha privileged her own ideas regarding the task as a way to establish and maintain her position of higher status.

However, in other instances throughout the video clip, Sasha listened to Lily's probing questions, implying that Lily was successful in countering her position of lower status. In Table 10, for example, we observed Lily initially questioning Sasha in Line 2. Sasha accepted this disagreement as she exhibited a submissive positioning move – leaned back in her seat. Lily continued voicing her reasoning (Lines 4 & 6), which led to Sasha doubting her position as team captain in Line 7 – "Did I type them in right?" – and simultaneously asking for help from Lily. As noted in Table 7, this interaction leads to cracking the enciphered message. As another instance, we observed the pair sitting idle, looking toward the laptop screen, which we assume indicated that each was pondering the enciphered message. A few seconds later, Lily noted that L was a single letter, and then directed Lily to enter 11. Sasha nodded her head and entered information into the laptop; again, being open and submissive to Lily's suggestion.

In the case of Lily and Sasha, analyses showed that Sasha was positioned as the dominant partner and often assumed and maintained higher intellectual status within her team – control of the team's laptop, denoting Lily as secretary, and privileging her own ideas. Lily, on one hand, was positioned as the inferior partner as she seemed to accept her position as secretary. On the other hand, we further observed Sasha rejecting her position of lower status through positioning herself as questioner. These instances were at times accepted by Sasha, yet other times, rejected by Sasha. Regardless, Sasha's benign dominance did not have any noticeable effects on the team's productivity and mutual engagement on the deciphering challenge.

Discussion

In both cases of technology-mediated collaborative problem-solving, we found that camper interactions around shared iPod and laptop resources—theorized as positioning artifacts—provided sufficient evidence for analyzing the negotiated power and status orderings within each partner team. We found status problems in both instances, as participants with more power and higher status had more control over what were intended to be shared technological devices and higher influence on the partner team.

Table 10

	Time	Lily	Sasha
1	5:33	*Looking toward screen.*	*Hits a key on keypad.* I.
2	5:35	Wait. Are we typing in these le::tters (0.4) to the::se letters? *Points from laptop screen with pencil eraser.*	*Hands are idle on keypad. Head directed toward laptop.*
3	5:39	*Still pointing to laptop screen.*	Pretty ↓sure.
4	5:48	Because if this is a big C, then (0.2) it would be F here. *Removes pencil eraser from pointing at laptop screen.*	
5	5:52		*Removes hands from keypad. Leans back in seat.*
6	6:07	*Points to laptop screen with pencil eraser.* So (.) if these are the big letters, then it would be like (0.4) C is like (.) you know.	*Reaches over with right hand and picks up the handout from the table – lying in front of Lily.*
7	6:15	*Leans back in seat. Still looking at laptop screen.*	*Places the handout on the table between the two.* ↑Maybe I didn't type that in right. Did ↑I type that in right?

Participants with less power and lower status had less control over shared technological devices and less influence on their partner team. Jasmine's blatant claims of ownership over shared resources reflected her assumed power and dominant positioning over Becky. Sasha's affable control over the shared laptop within a productive, collaborative problem-solving zone reflected her benign dominance and higher status positionings over Lily. These claims are consistent with research about the harmful—and predictable—effects that status problems have on collaborative groupwork (Cohen and Lotan 1995; Cohen and Lotan 1997), including the uneven participation patterns and power imbalances we observed for both teams.

We also found that the negotiated power and status orderings within each partner team sanctioned and solidified camper interactions around shared technology resources over time, thereby strengthening the higher-status partner's position of power on the team. Even after the higher-status partner established control over shared technology resources and negotiated a more powerful positioning, the higher-status partner continued to exert and maintain control over the team's technology. Jasmine escalated her position of dominance over Becky, which exacerbated her possessiveness over her team's laptop and iPod. Sasha's negotiated position as team captain made space for her sustained monopoly with typing rights. Although power and status are necessarily under constant negotiation, the early status orderings we observed proved intractable for the partner team interactions we analyzed. Taken together, our analysis supports a reflexive relationship between partner interactions around shared technology resources and negotiated positions of power and status, which leads us to conclude that interactions around technology function as an important indicator of negotiated positionings of power and status in CSCL settings, and vice-versa.

With that said, we found qualitative differences in the ways emergent status problems impacted each team's productivity with the cryptography challenge. Jasmine positioned herself as the higher-status team member and Becky as an intellectual inferior. We argue that Jasmine's physical control over shared technology resources and invasion of Becky's personal space denied Becky access to essential resources, to full participation, and to a collective problem-solving space. Our analysis thus suggests that Jasmine's positionings of superiority over Becky had a substantial negative impact on Becky's opportunities to engage productively with the cryptography challenge. Jasmine's overt exertions of status and power also negatively impacted Jasmine, as closing herself off to a partnership with Becky eliminated the possibility of benefitting from the learning potential inherent to participating in small group work (Cohen and Lotan 2014), such as explaining your thinking to partner in order to gain clarity on a mathematical idea.

We found differences in status orderings in the interactions between Sasha and Lily as well, with Sasha positioned as the uncontested higher-status partner, although Sasha's negotiated positionings did not have noticeable effects on the team's productivity and mutual engagement on the deciphering challenge. These differences were subtle at times, as Lily and Sasha's interactions were consistent with research on "good groupwork" in computer-supported collaborative learning environments (Arvaja et al. 2008; Cohen and Lotan 2014). The differential status orderings we found in our analysis therefore did not appear to have noticeable effects on Lily and Sasha's opportunities to participate fully in and contribute meaningfully to a collaborative problem-solving task.

Subtle displays of problematic participation and power imbalances—such as those negotiated and reified by Lily and Sasha's interactions around the iPod and the laptop—

are easy to miss. For example, uneven participation patterns and power imbalances may go undetected when engagement appears strong and learning outcomes are met. Lily and Sasha displayed indicators of "good groupwork" that are typically associated with the benefits of CSCL learning environments, and yet we still found evidence of status problems in their team. Our analysis confirms that it is a myth to assume that negotiated positionings of power and status are a non-issue for groups who display behaviors consistent with "good" CSCL settings where everything "goes right." With that said, we do not mean to imply that something is wrong in such instances; instead, our analysis raises questions about the relative impact of uneven participation patterns and power imbalances on learning, and what pedagogical interventions could *or should* be applied in these situations. Analyses of "good" student interactions around technology through the lens of positioning theory—groups who appear to be highly engaged and meet learning goals—may advance our understandings of the subtle ways in which the practices and conditions surrounding CSCL environments impact learning.

Implications for practice

Obvious displays of problematic participation and power imbalances, such as those negotiated and reified by Becky and Jasmine's interactions around technology-mediated positioning artifacts, corroborate existing findings on problematic CSCL environments and highlight the need for pedagogical interventions that explicitly attend to issues of power and status (Perrotta and Evans 2013). Although there are many ways to approach these professional dilemmas, research on complex instruction (CI) is especially useful for conceptualizing and enacting classroom intervention strategies that minimize the harmful effects of status since it explicitly attends to issues of positioning and negotiation of authority in collaborative settings (Cohen 1994; Featherstone et al. 2011; Horn 2012; Nasir et al. 2014). Well documented strategies like noticing and naming student strengths through the practice of assigning competence, implementing strengths-based tasks, and making space for fair positionings of technological devices and other resources through procedural team roles are promising levers for productively shifting power within the small group (Cohen 1994).

One strategy for minimizing the ill effects of status on the small group is to assign competence to low-status students whose contributions are not being heard by their partner or group members (Cohen and Lotan 1995; Cohen and Lotan 1997). In assigning competence, educators publicly acknowledge the genuinely intellectual contribution made by the student that was relevant to the task at hand. Another powerful strategy documented in the CI literature involves a strengths-based orientation to a performance task, where educators point out the specific strengths that will be needed in the task—e.g., experimenting, tinkering, using computers as dynamic thinking tools—followed by a public statement that no one will be good at everything but everyone will be good at something and be able to contribute to the task (Cohen et al. 1999). Although the particulars necessary for successful implementation of assigning competence and strengths-based task orientation exceed the scope of this manuscript, we briefly feature these examples in order to connect the status dilemmas we found in our analysis with empirically researched-based teaching practices likely to leverage equal-status interactions.

Limitations of the study

Although the findings from our study suggest clear implications for research and practices, the results from this initial small study are not generalizable to all CSCL settings. First, our analysis was limited to two contrasting all-female cases within a mathematics summer course focused on cryptography. Future studies across CSCL environments will aid in building a cumulative research base regarding negotiations of power and status around technological resources, among students of all ages. Second, neither our research questions nor the data we collected and analyzed allowed us to make claims based on a participant's self-identified gender and/or race. It is imperative that future research directly attends to issues of gender and race so that honest accountings of marginalization, dominance, and power become an explicit part of the conversation in extant CSCL literature (Lyons et al. 2016; Martin 2006). Third, we did not have access to participants after the camp ended, so we did not have an opportunity to conduct any member checking or follow-up interviews that would allow us to propose explanations for participation patterns and power dynamics from the participants' perspectives. Hence, a similar study could include stimulated recall interviews with participants as a means to gain additional insight regarding their perception.

Conclusion

Our analysis of partner interactions around technology contributes to the CSCL literature by corroborating and expanding empirical connections between technology-mediated collaboration and issues of positioning, status, and power. There is some evidence of positive empirical relationships between collaborative groupwork and technology-mediated positioning artifacts within current research (e.g., Janssen et al. 2007; White 2006). Even so, these relationships should still be questioned, especially in context of studies framed by social theories of learning, where learning is defined as a process of becoming through participation rather than a process of knowledge acquisition. This is an important point to consider in the context of our findings related to differential engagement in collaborative problem-solving activities. If learning is something that happens through social interactions, then we argue that it is our responsibility to attend to ways in which negotiations of power and status in computer-supported collaborative learning contexts influence participation patterns and opportunities to participate meaningfully in technology-mediated, collaborative problem-solving tasks (Perrotta and Evans 2013).

These issues are becoming increasingly important in CSCL settings. Computer science and maker-related programs are on the rise (e.g., Kalelioğlu 2015; Peppler et al. 2017), as are bring your own device initiatives (e.g., Song 2014) and one-to-one classrooms (e.g., Lei and Zhao 2008; Penuel 2006). Our analysis thus brings a sense of urgency to research that investigates the impact of negotiated positionings of status and power on the design and implementation of technology-mediated collaborative learning initiatives in K-12 and postsecondary schools (Barron 2003; Q17 Hirsch 2007; Lai et al. 2013). Q18 The field would greatly benefit from continued research that builds upon and expands our theoretical and practical understandings of these critically important, complex relationships.

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Appendix

Table 11 Example of the five-column format

	Lily		Sasha		Other	
Time Stamp	Nonverbal	Verbal	Nonverbal	Verbal	Nonverbal	Verbal
0:01	1. turns head to behind her	1. Alright.↑	1. laptop is positioned between the two; holding iPod in right hand			
0:06	2. turns head toward handout	2. So we can do these (.) right?	2. lays iPod on table – her right hand side; grabs base of laptop with both hands and turns slightly in her direction; moves mouse			
0:09			3. moves to keyboard – no typing; picks up iPod with right hand, but then lays back down on table; turns to look at Sarah		3. stands between the two girls; points to first problem in handout; points to other pair at table	[Suzanne] 3. Yeah, so these ones, (0.3) do you know the key that you did before with their message?

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