When Face-to-Face Fails: Opportunities for Social Media to Foster Collaborative Learning

Tamara Clegg, Jason C. Yip, June Ahn, Elizabeth Bonsignore, Michael Gubbels,
Becky Lewittes, & Emily Rhodes
{tclegg, jasonyip, ahnjune, ebonsign, mgubbels, charley, eerhodes}@umd.edu
University of Maryland, 2117 Hornbake South Wing, College Park, MD 20742

Abstract: Productive collaboration is an integral component of socially constructed perspectives of learning. Yet effective collaboration is quite challenging and not without its own risks. Collaboration, both distributed and face-to-face, must be nurtured; technologies can support or undermine its positive growth in learning communities. We present an exploratory investigation of the types of social interactions that are both productive and non-productive in face-to-face informal science learning contexts. We include an analysis of the ways in which social media technologies can be designed to support more collaborative interactions.

Introduction

In our work, we aim to help learners see personally relevant aspects of science and begin to develop more scientific dispositions. Doing so involves helping learners see the social side of science and engage in scientific conversations with peers and adults who share their interests (Clegg & Kolodner, 2013). Productive collaboration is an integral component of such socially constructed perspectives of science learning. We seek to support collaborative dialogue among learners, their peers, and adults that involve the scientific inquiry practices of asking questions, designing experiments, collecting data, and developing claims (Chinn & Malhotra, 2002). However, effective collaboration is not an organic element of group-based scientific investigation (e.g., Barron, 2003). Collaboration, both distributed and face-to-face, must be nurtured; technologies can support or undermine its positive growth in communities of learners. While work has begun to address the needs of CSCL environments for supporting physically distributed groups, less is known about the potential of CSCL for supporting the social interactions of face-to-face groups. Alternatively, CSCW research has begun to look at the social interactions learners have in face-to-face environments when using collaborative technology. However, this research area has traditionally focused on the social difficulties learners encounter with collaborative technologies (e.g., virtually violating social norms) (Morris, Ryall, Shen, Forlines, & Vernier, 2004). In this paper, we look at the difficulties learners face when collaborating in face-to-face environments and ways in which CSCL technologies can help learners address these difficulties. Specifically, we ask: (1) *How can CSCL technology augment face-to-face environments to promote the productive social interactions necessary for collaborative learning?* and (2) *How do design features in CSCL technology facilitate productive social shifts?*

Background

In the context of scientific inquiry, the aspects of collaboration that we aim to promote include: sharing original insights and divergent ideas, providing critiques of one another, observing the strategies of others, building communal knowledge through conversation, and drawing on the expertise of others (Barron, 2003; Puntambekar, 2006). Yet effective collaboration is quite challenging and not without its own risks. When practiced in uninformed ways, collaboration can have negative effects, such as stigmatizing low achievers and creating dysfunctional interactions. Effectiveness often depends on such factors as how groups are organized, what the tasks are, and how the group is held accountable (Blumenfeld, Marx, Soloway, & Krajcik, 1996).

Cognitive Support for Collaboration

CSCL researchers have begun to address some of the challenges learners face with collaboration, and scientific inquiry more specifically, through the design of technology. For example, virtual spaces allow learners to connect across physical locations, share their experiences with one another, and build on one another's understanding (e.g., Scardamalia & Bereiter, 1996). This line of work has also shown that the structure of learning environments can often prevent or promote collaboration. For instance, the nature of the problems learners work on can play a role in fostering or prohibiting collaboration. Researchers have found that complex open-ended problems that utilize multiple elements of knowledge are best suited for collaborative learning because such learning situations impose more cognitive requirements on learners (Janssen, Kirschner, Erkens, Kirschnker, & Paas, 2010). However, Janssen et al. (2010) also observed that working collaboratively imposes additional costs for learners, particularly the costs associated with coordinating group members and developing positive social relationships.

Social and contextual factors of collaborative learning come in many forms and impact learners' cognitive processing. For example, competition in learning environments can prevent positive collaborative actions. Rick and Guzdial (2006) found that when university faculty did not have attitudes receptive of collaboration, the use of collaborative technology (i.e., wikis) in those classes was hampered. Likewise, when students expect teachers to drive the learning environment and be the director of discussions in CSCL environments, their motivation to collaborate is low (Kreijns, Kirschner, & Jochems, 2003; Puntambekar, 2006). These factors impact collaborative behaviors and affect the cognitive processing that learners can do together. For example, successful learning groups build discussion on their peers' previous contributions, attend to members' proposals and ideas, and pursue promising proposals jointly (Barron, 2003; Stahl, 2006). Positive group dynamics may enhance these collaborative learning behaviors, while negative group dynamics hinder them. This prior research, focusing on cognitive aspects of collaboration, illustrates that if we do not address the social aspects of collaboration, many learners will not experience the cognitive benefits of collaboration.

Social Support for Collaboration

Recent work has begun to focus on supporting learners' social interactions in CSCL environments. This work points to the importance of technology stimulating and promoting learners' social interactions (sociability) and prompting social presence, or the awareness of others in CSCL virtual environments. This research suggests that CSCL environments promote sociability by establishing two-way connections between distributed learners, enabling them to exchange diverse media forms (e.g., video, audio, text) as a means of stimulating interactions. Social presence can then be promoted non-technically in CSCL environments through such techniques as inclusion of moderators and training of participants on how to create social presence (Kreijns et al., 2003).

Many educational environments are termed blended learning, combining face-to-face interaction with distributed work using CSCL tools. Existing systems, such as WISE (Linn, Clark, & Slotta, 2002), have tools that support learners' scientific inquiry in such blended learning experiences. However, these technologies often specify what investigations learners will pursue and how they will go about their pursuit. Teachers or adult technology designers often take the collective cognitive responsibility (Scardamalia & Bereiter, 1996) for scientific inquiry processes. While collaboration and sharing across groups is supported in features of the system, collaboration is often a secondary focus to the individual or small group work of learners as they interact with teachers. On the other hand, systems like Knowledge Forum and wikis (Scardamalia, 2004) were designed to give collective cognitive responsibility to learners as they engage in inquiry. Collaborative cognitive work is foregrounded as learners strive collectively to build a shared knowledge base. While these knowledge-building systems seek to promote interaction with ideas, we aim to promote *engagement* in investigation, particularly to inspire young children to act, investigate, and experiment in their everyday lives. More work is needed to understand how CSCL technologies can support face-to-face interaction during learners' scientific inquiry experiences. Our work begins to address this gap in promoting social processes of blended scientific inquiry learning environments by investigating one face-to-face learning environment supported by technology in which both the environment and the technology were designed to promote scientific collaboration. We found the learners in this particular group had significant difficulties engaging in face-to-face, whole group conversations. Yet, working in an online community designed to support science inquiry seemed to shift the atmosphere of the physical setting. In this context, we aimed to understand the ways in which social media technologies supported more productive collaborative interactions.

Design of Social Media to Support CSCL

In this study, we used a CSCL tool called SINQ (for ***S**cientific **INQ**uiry*) (Ahn, Gubbels, Kim, & Wu, 2012), which leverages social media (SM) features to promote collaborative scientific inquiry. SM platforms, where individual members network, share information, and socialize are now a fundamental paradigm in computer-mediated communication (O'Reilly, 2007). SM technologies inherently tap into the sociable desires of individuals and thus may offer insight into ways of designing social support for collaborative learning. To date, researchers have focused on the literacy practices that young people enact in SM sites (e.g. Greenhow & Robelia, 2009), but little research has been conducted to examine how SM can provide scaffolded social support in areas such as science learning. Popular SM communities illuminate the different ways in which individuals want to engage with others, share knowledge, and incorporate online interaction into their daily lives (Shirky, 2011). For example, Wikipedia uses a wiki framework that allows thousands of individuals to contribute their knowledge, vet others' contributions, and in the process create a worldwide encyclopedia resource. In news sites such as Reddit, members vote up interesting posts, which then become a vetted source of information for the rest of the world.

We drew upon these SM approaches in the design of SINQ. SINQ is designed to enable distributed individuals to aggregate their micro-contributions into coherent science projects (called "challenges"). Members in SINQ do this in several ways. First, anyone in SINQ can contribute a question, hypothesis, or project idea to the system. In addition, any member can add a piece of the inquiry process to any peers' prior contribution. For example, Member 1 might contribute a question they wonder about in their everyday life; Member 2 might add a hypothesis to test this question; and yet another Member 3 may devise a project to test the hypothesis. This framework taps into several features of SM platforms: (a) individuals can make micro-contributions to the inquiry process in ways that relate to them, or fit with their current skills and dispositions; and (b) the SINQ system aggregates these micro-contributions into coherent projects that members can try in any formal or informal setting. A second SM feature of SINQ is voting as modeled in Facebook and Reddit. These mechanisms were included in SINQ to be sociocultural tools for learning that allow collaborative groups to negotiate and vet norms of quality. In SINQ, the voting mechanisms ask members to reflect on what makes a good question, hypothesis, or project. For example, members can vote on whether questions are novel, whether the question is relatable, or if they spark curiosity and wonder. Votes on these criteria are incorporated into SINQ as the system aggregates pieces of inquiry into whole projects. In addition, it is possible that learners are implicitly guided to consider these criteria when posting new questions. We used SINQ for scientific inquiry activities within a particular science-learning context, *Kitchen Chemistry* (KC).

Design of Kitchen Chemistry (KC)

KC is an after-school program in which learners engage in scientific inquiry through cooking. In the first four sessions of KC, learners engage in *semi-structured activities,* becoming familiar with processes in measurement, data collection, and technology usage in the context of cooking experiments aimed to answer scientific questions (e.g., What do eggs do in brownies?). On *Choice Days*, learners are given opportunities to use what they have learned to develop questions, hypotheses, experimental procedures, and data collection techniques for their own food investigation. Learners make decisions on what recipes they want to modify, what variables they will control, what data to collect, and how to interpret their findings. In planning for Choice Day investigations, learners used SINQ to develop questions and hypotheses for their food investigations.

Methods

For this study, we employed the methods and standards of a comparative case study (Yin, 2003). The case is a single 12-week implementation of KC. Within this single implementation, we examined multiple units of analysis: the whole group discussions and three participant and facilitator interactions with SINQ. In this exploratory study, we examined the distractions and contributions that occurred during whole group discussion and the ways in which participants and facilitators interacted using SINQ.

Context and Data Collection

KC was implemented as a 12-week afterschool program that met once a week for roughly two hours in a local private school. Six learners between the ages of 8 to 11 participated in the program each week. The learners all attended the Montessori school that hosted KC. Anecdotally, parents and teachers told us that since KC provided a more hands-on approach to inquiry, the program appeared attractive to children with many difficulties in attention and interpersonal social dynamics. Each day we collected video recordings of all activities and discussions. As a part of a larger study, interviews were conducted with four of the learners and their parents at two intervals of the program. Lead facilitators also recorded post-observational field notes of their experiences each day in KC. Lastly, we collected analytics (e.g., time stamps, account logins) as participants logged onto SINQ and posted responses. The facilitators in KC in the case studies are Tammy, Jason, Mike, Beth, and Charley. All learners' names are pseudonyms.

Our goal was to understand learners' interactions across groups. We therefore analyze these interactions where they were most prevalent – in whole group conversations and in learners' interactions with SINQ. First, we characterized face-to-face whole group conversations. We aimed to understand aspects of the community that made conversations difficult and ways that SINQ mitigated some of these social issues. We transcribed three different whole group conversations in KC: Days 1, 4, and 5. These days represented a range of goals we had during whole group conversations, such as introductions (to learners, facilitators, and the program) and discussions about observations of experiments. We took a hybrid inductive and deductive coding approach, coding conversations by the productive aspects of learners' conversations and the points of social breakdowns. We used open coding to identify social breakdowns, which included episodes in which we experienced problems engaging learners in a community conversation (e.g., learner distractions, interruptions, and peer arguments). Clips in the category of learner productivity included those that were deductively coded as involving the types of scientific inquiry practices our program was designed to promote (e.g., asking scientific questions, making claims, generating evidence), based on existing frameworks for scientific practice (e.g., Chinn & Malhotra, 2002). Engagement in these practices in whole group conversation would then involve the types of productive collaboration others have called for (e.g., sharing ideas, understanding different perspectives) (e.g., Barron, 2003). To verify that our sample of whole group conversations from the first half of KC was representative of ways in which we observed participants interacting throughout the program, we also reviewed a subset of conversations on later days (Days 7 and 12). We confirmed that the codes we identified as occurring early in the project timeline retained similar frequency patterns throughout the program.

To examine learners' interactions with SINQ, we selected three video clips of learners interacting with the app, and coded the interactions using the same conversation breakdown and productive conversation codes. We also triangulated the clips with analytics from SINQ, interviews with learners, and our field notes. Once each of the cases was developed, we conducted a cross-case analysis of learner interactions using SINQ and whole group discussions to determine patterns in the data. Our coding of learners' interactions for productive and non-productive conversations offered key points of comparison between whole group discussion characteristics and learners' interactions in SINQ that then inform design implications.

Key Findings

In this section, we first summarize face-to-face breakdowns and productive conversations noted in the whole group discussions. Second, we present three cases, focusing our analysis on interactions with SINQ.

Whole Group Discussions

Four codes emerged from our data that characterized non-productive contributors to whole group discussions:
1. Competing foci: Learners were often focused on different aspects of the environment (e.g., the discussion, objects they could play with) or other ideas and topics that were unrelated to the learning context (e.g., songs, games). It was therefore hard for learners and facilitators to have a continuous large group conversation.
2. Talking out of turn: Learners often interrupted one another (and facilitators) with off topic musings such as loud noises, singing, or loud speech.
3. Learner derailing: As learners began to have outbursts, others would engage in the disruptive behavior as well. This behavior caused conversations to breakdown completely and often frustrated the facilitators.
4. Learner arguments: Some learners often got into social disagreements with one another that distracted them from the conversation. Two learners in the group, Donna and Anthony, were often in conflict. They would get into verbal arguments and small scuffles that demanded facilitators' attention during whole group conversations.

However, there were times when learners engaged in productive conversations. Across all of the clips coded as involving scientific contributions, we coded learners' generating evidence (3 instances), making claims (4 instances), and making observations (1 instance). Despite several instances of productive contributions, these clips were also interspersed with non-productive and interruptive behaviors. For example, on Day 4, while we discussed the "why" behind their cooking experiment, only one participant, Skylar, engaged in more than two turns of productive conversation. Overall, only two learners, Skylar and Arman, appeared to be on task. Anthony and Donna argued and had to be reprimanded while Freddie made noises, playing with the iPad and exacerbating Donna and Anthony's fights. Therefore, even during productive conversations, the environment was often still loud and facilitators often found it hard to manage the group to achieve our collaborative goals.

SINQ Interactions

In this section, we outline three cases of learner interactions with SINQ, to compare and contrast with our whole group discussion findings. In each case, we describe the interaction, followed by a brief analysis.

Case #1: Freddie and Eric

On Day 5 of KC, Freddie, a 10-year-old participant, worked with Tammy (facilitator) to develop his ideas for Choice Day in the SINQ platform. Although Freddie was initially distracted (i.e., playing with the research video cameras), he became intently focused on the activity once Tammy prompted him to consider an idea he had previously expressed interest in, making green brownies or "Greenies." As Tammy read Freddie's initial question in SINQ, "How should I make green brownies?" she prompted him to develop an experimental question to answer, as well as a hypothesis for the experiment. Tammy also reminded Freddie about a prior brownie experiment varying the number of eggs. Based on the past experiment, Freddie decided to increase the number of eggs in the new Greenies recipe because he thought that would make their brownies chewier. Although he was distracted again for short periods, he would return his focus to SINQ on his own.

Later, he became slightly distracted when the room lost Internet connectivity. As we regained Internet connectivity, SINQ was initialized back to the home page with all the learners' contributions. This incident prompted Freddie to read others' questions and ideas. Tammy asked him about some of the criteria SINQ uses to describe questions. Initially, Freddie told Tammy he was just voting for all of the questions. However, when they discussed other groups' questions he pointed to specific questions he wondered about and those to which he could not relate. Freddie was also able to get feedback from others on his own idea in SINQ. As he commented on others' questions, Freddie observed that someone had recently voted his question up. He also heard from a facilitator that another learner, Eric, had feedback for him. Interested to hear Eric's feedback, Freddie went over to Eric to learn more. However, Eric wanted to enter his hypothesis in SINQ first. Freddie continued to ask Eric if he had posted his hypothesis yet. Once he was done, Freddie and Eric looked at the iPad™ together, while Freddie read Eric's hypothesis out loud. Before leaving for the day, Freddie made sure to get his username and password for logging onto SINQ from home. Later, from home, Freddie provided a hypothesis for Eric's first question in SINQ: "If I use 1 cup of baking soda and 1 cup of vinegar, how much explosion will I get, and how big will it be?" Posting a link to a slow motion video of baking soda being mixed with vinegar and foaming, Freddie replied to Eric, "4 and answer see this video…" In subsequent Choice Days, the two learners devised two variations of the same experiment (one making Greenies: green brownies; the other Whities: white brownies).

Case #1 Analysis

Two aspects of this case warrant attention. First, Freddie was one of the learners who, in whole group discussions, had to be reprimanded often for non-productive contributions, such as disruptive comments and noises. However, as we worked on SINQ, Freddie was more focused on the goal of the activity than he was during whole group discussions. Although he became distracted at points, he was easily prompted back to the activity or he brought himself back to it. The second important aspect of this case is Freddie's interaction with Eric. Previously, the group often ostracized Eric for talking out of turn frequently and loudly. During whole group conversations, Freddie and Eric only interacted when Freddie reprimanded Eric. However, on the day learners used SINQ, Eric was able to read about Freddie's idea from afar and think of feedback to give him in a non-disruptive way. As Eric wrote his hypothesis for Freddie in SINQ, the social landscape of the group was altered. Instead of pushing Eric away, Freddie was able to see that they had a common interest in his idea and he began to seek Eric out for his input. Their common interest persisted beyond the session in KC and at home.

Case #2: Donna and Anthony

For this second SINQ session, Donna, an 11-year-old girl, worked together with Jason (facilitator). Sitting next to them were Anthony, a 10-year-old boy, and Tammy (facilitator). Donna and Anthony were close friends from school, but they often got into arguments. They were the primary learners who were distracted during whole group discussions by arguing with one another. In this exchange, the physical positions of the interlocutors are important to note. From left to right, the group was seated next to each other as follows: Donna (child), Jason (adult), Anthony (child), and Tammy (adult).

As they began planning for Choice Day, Anthony did not have an idea about where to start. Tammy prompted him to refer to other questions previously entered into SINQ for ideas. Meanwhile, Jason was working with Donna who immediately had an idea of what to make for Choice Day, exclaiming "PUFFLES!" Jason worked with Donna to refine her idea to create a question in SINQ. Donna replied, "Ok, so they are these little balls of, ah, that are like cupcakes and they, you cover them with like some kind of hard sugar." As Donna excitedly detailed her "Puffles" to Jason, Anthony was glancing in Donna's direction. When Tammy asked Anthony if any of the prior food questions inspired him, Anthony replied, "Let's see, what do I want to make to compare to Donna's?" Instead of referring to SINQ entries for a Choice Day idea, Anthony chose to refer to Donna's idea. Meanwhile, Donna stopped typing her question into SINQ to talk more with Jason. As she talked about the hard sugar coating, Anthony responded to Tammy, "I like candy." Tammy prompted him to transform his thoughts about candy into a testable question. At this same moment, Donna repeated to Jason that her question was about "a hard sugar." Hearing this, Anthony quickly came up with the question, "Why are most candies hard?" At this point, Donna's hard sugar inquiry and Anthony's hard candies question were distinct enough that the children did not notice. The SINQ analytics data show that Anthony's question, "Why are candys hard?" was recorded before Donna's "How do you make a hard suger?"

Later, Jason and Donna discussed how the Puffles coating would be like "jawbreakers," with Anthony again listening in. Tammy, who did not hear Jason and Donna's conversation, asked Anthony, "Now what kind of project do we need to do to answer that question?" Anthony replied, "Well we could, we could make kind of like a *jawbreaker* thing and like put..." The moment Anthony said "jawbreaker", Donna immediately and angrily yelled to Anthony, "You just take it from me!" Almost instantly, Anthony retorted, "No, I'm not!" and continued to tell Tammy how he would make a candy in the same type of hard sugar coating. Donna, in complete frustration, told Jason, "I never should have said it out loud!" Jason tried to assuage her, but she irritably folded her arms inward and stated, "Puffles was my idea! Then why is he stealing it?" At this moment, Jason guided her away from the situation, leading her outside the classroom to devise a new question.

Case #2 analysis

Donna and Anthony, while close friends, often could not work together in close physical proximity. In interviews, Donna called herself a "designer" and often had many ideas she wanted to develop. However, Anthony was at a different stage of question development than Donna. He had never used SINQ before and had not developed an investigation question on his own. Because Anthony and Donna were coming at the SINQ activity from two different levels of understanding, their physical proximity may have conflicted with what each of them needed. In a later interview with Donna, she said that the "stealing" of her idea made her feel "mistreated, like, they (referring to Anthony) didn't think that it, it was mine." In this case, an interesting difference between the face-to-face and virtual environment is highlighted. Having an idea upvoted requires others to see and like your idea; this can be a form of social currency. But, for Donna, being face-to-face with another learner meant giving access to her idea verbally before it was attributed to her. This situation was problematic and led to conflict over authorship. However, this does not suggest that Donna did not want to interact with others' ideas. In the beginning of this session, Donna was browsing prior questions that had been written in the first SINQ session. Because both learners were at different points of ideation, in addition to learning new norms for participation, physically separating them may have allowed Donna to have authorship over her own idea first and then refine her idea while considering others' SINQ contributions. Conversely, Anthony may have been less tempted to overhear Donna's idea so he could instead focus on existing questions in SINQ to help inspire his own questions.

Case #3: Arman

In the first SINQ session, Arman, a 10-year-old boy, worked with Mike (facilitator) to devise an investigation. Arman was often relatively quiet in whole group conversations. His experience with SINQ sheds light on the ways in which SINQ facilitated conversation between him and the adults working with him, as well as his development of questions and an experiment. Initially, Arman did not have an idea for his investigation, and instead asked Mike for an idea. Mike randomly told Arman, "cinnamon goo," an idea Arman latched onto. At this point, Mike generated a question for Arman, "how can they be even more cinnamony?" Here, Arman asked, "Isn't like cinnamon like that stick?" Mike explained how cinnamon sticks are ground into powder. During this explanation, Arman began to type his first question into SINQ, "How does cinnamon relate to cinnamon rolls?" As Arman worked, SINQ's interface prompted him: "Do you wonder about this?" Using this prompt, Arman vocalized his thoughts on cinnamon, "because cinnamon, actual cinnamon is a solid thing." Mike interpreted Arman's response as a comparison of cinnamon sticks to cinnamon powder. Arman and Mike then discussed the nature of cinnamon and where it comes from. Concurrently, Arman scanned some of the questions other learners posted. Arman typed in his second question, "How do they make cinnamon sticks?"

While Mike responded to technical SINQ issues, Jason and Charley (both facilitators) recommended to Arman that he use SINQ to vote on other children's questions. As Arman did this, Charley asked Arman about his question. Arman explained his transition from the first and second question. Charley began a series of prompts to learn more about why he chose to explore cinnamon sticks and cinnamon rolls. Arman explained that cinnamon rolls are very sweet and "cinnamony". Probing for more detail, Charley asked, "is there such a thing as too sweet?" Both of them discussed what they thought is sweet and their experiences with the rolls. At this point, Charley asked Arman to consider working on a recipe for the rolls that would determine the amount of sweetness in the roll. Arman entertained the idea and entered a third question into SINQ: "How do they add the cinnamon to a cinnamon roll?" As Arman added his question, Charley shared how cinnamon is sprinkled between layers of dough. Building on this, Charley also suggested different ways to think about how to add the cinnamon into the dough (e.g., different flours or sugars, in-between layers or outside the layers). This discussion inspired Arman to develop another question: "Wich would taste more cinnaminy: cinnamon in the doe or cinnamon in between the layers."

Case #3 analysis

Arman's question development process iterated through several stages. To start, Arman needed a seed of encouragement. In his interview, Arman expressed a sense of initial anxiety for the investigation development: "…I got really worried about what I should do." However, working together with Mike, Arman felt better and more confident for the task: "and then somebody brought up cinnamon and I brought up cinnamon rolls. And then I had my questions for that." Second, the process of seeing other learners' questions helped Arman to see how his friends were contributing. He was able to see the questions and guess who authored them. Third, the prompts from SINQ sparked learner and facilitator conversations about scientific questions and evidence. For instance, SINQ asks learners to vote up questions by asking them to consider, "do you wonder about this?", "is this a novel question?", and "can you relate to this question?" As Arman followed these prompts, Mike asked him if he ever considered questions about cinnamon, which prompted Arman to ask about cinnamon's composition, and how cinnamon sticks relate to cinnamon powder. From one prompt, Mike and Arman were able to elaborate on cinnamon's transition from stick to powder, a line of reasoning that led to more discussions about how cinnamon is added to the rolls.

Discussion

In looking across cases, we observed three ways in which SINQ augmented the face-to-face environment to promote social interactions. First, SINQ facilitated *changes in the social dynamic* between group members by fostering shifts in learner's relationships with one another. The technology affordances helped bring some who were initially separate together, and others who were initially inseparable further apart. However, in both cases learners needed to be separated so that they could begin to work together. The technology then afforded and enabled such distanced collaboration. In Freddie and Eric's case, SINQ helped two learners who were previously socially distant to find common interest with its social question-sharing features. In contrast, Donna and Anthony's work in close proximity with SINQ prompted a heated argument. After the angry exchange, Donna began to sign all of her SINQ entries under an alias ("the DESTROYER"), so that Anthony would not recognize her contributions. In this way, a technical feature enabled distance between the two learners, which the facilitators had to impose to be productive distance, so that they could focus on scientific collaboration.

The second way the technology affordances helped augment the face-to-face environment was in *fostering collaboration across groups when learners were ready*. SINQ provided ways for learners to interact individually in the face-to-face environment, yet still collaborate virtually in a scaffolded inquiry process. This enabled learners to focus on the activity without getting distracted by one another. Learners could then individually choose opportune times to find out about what others were doing and sharing. In this way, many of the breakdowns we experienced in whole group conversations (e.g., learner derailing) were either no longer a problem, or addressed more easily and quietly individually. Once learners were able to focus on the activity and collaborate virtually, they used the technology to engage in the collaborative processes we aimed to promote (e.g., sharing original insights). In each case, learners browsed and voted on one another's science questions according to the standards put forth in SINQ. This process helped them to be aware of others' ideas and to consider them scientifically (i.e., in choosing whether or not and how to vote them up or down).

Finally, the technology afforded *enhanced collaboration with facilitators*. Across the cases and in other non-represented cases, the types of questions SINQ asked learners to vote on (e.g., is this a novel question, can you relate to this question), and the process of voting questions up and down fostered conversations between facilitators and learners about what it meant to ask and evaluate scientific questions. Facilitators often needed to help define or differentiate the questions SINQ asked for learners to understand and answer them. This helped to set standards in the group for good questions, as learners were applying those standards. In addition, observing or having access to what other groups were doing in real time helped facilitators to foster connections with learners. For example, Eric's facilitator Beth was able to connect Freddie and Eric because they had seen Freddie's question on SINQ. Moreover, Charley and Mike used the prompts and context to help Arman come up with his cinnamon rolls question.

Design Implications and Conclusions

Our analysis points to several affordances of CSCL technology to facilitate productive social shifts in face-to-face learning environments. First, our analysis highlights the importance of providing *support for facilitating scientific communication*. Specifically, CSCL technology should show other learners' contributions at relevant and opportune times. Our findings show that there are ways in which SINQ provided such affordances and ways that it did not. In particular, we came to appreciate the importance of documenting ownership of ideas to prevent communication breakdowns. Our analysis emphasizes the need for technology that provides support for giving learners credit and protection of their ideas as they collaborate with others. The concept of authorship is particularly salient in a platform like SINQ, where individuals are asked to contribute pieces to a larger product, and thus give up some of their sole authorship in the inquiry process. In facilitating scientific communication, our findings also point to the importance of *a community repository* for enabling learners to put their ideas together and quickly provide feedback on one another's contributions. Voting mechanisms can then work well for prompting learners' scientific reflection and helping them to consider common interests. Providing learners with *multiple entry points into science*, or multiple ways in which to make contributions, is also important for supporting the social aspects of learners' collaboration. SINQ facilitated these different entry points by allowing learners to contribute different pieces of the scientific inquiry process.

Finally, our analysis underscores the importance of *factoring the learning context into the design and implementation of CSCL technology*. Specifically, our program was situated in a Montessori school where learners are acclimated to a culture of individual work and learning pace. The context in which we used SINQ more closely resembled that culture than our whole group conversations. Yet, we still needed learners to work together, to hear one another's ideas, and learn from each other. SINQ provided a means to strive toward both goals, as learners could work individually in the face-to-face environment, yet still share and hear one another's ideas, provide feedback, and recognize common interests. Our work suggests that CSCL designs that embed social affordances can help to foster productive changes in collaboration styles when needed, and can be used to alter the culture of face-to-face learning environments that are more individually focused. Previous CSCL work (e.g., Rick & Guzdial, 2006) suggests that there must be a culture of collaboration established in the learning context for computer-supported collaboration to be effective. Our work, however, moves outside of the classroom and looks at the challenge of supporting learners' social processes and their modes of working and communicating with one another.

Much of the CSCL, CSCW, and online communities research focuses on how technology can bring people together. Our work shows that CSCL tools sometimes need to provide separation to help learners begin to internalize the social skills needed for effective group work. SINQ explicitly scaffolded a collaborative process where individuals are asked to contribute pieces of inquiry and build from others' contributions. As our learners used SINQ, they were guided implicitly to work from this paradigm, which then facilitated their face-to-face interactions in productive ways. Based on these findings, we suggest that CSCL technology can actually bring learners closer together when face-to-face interactions are difficult. Perhaps next steps would be to explore how CSCW frameworks for identifying and addressing social conflicts (e.g., Morris et al., 2004) arising from use of collaborative technologies might apply to addressing conflicts arising from face-to-face interactions.

References

Ahn, J., Gubbels, M., Kim, J., & Wu, J. (2012). SINQ: Scientific INQuiry learning using social media. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12), Austin, TX* (pp. 2081 - 2086). New York, NY, USA: ACM.

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences, 12*(3), 307-359.

Blumenfeld, P., Marx, R., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher, 25*(8), 37-40.

Clegg, T., & Kolodner, J. (2013). The role of life-relevant learning environments in helping middle-school learners develop more scientific dispositions. Manuscript submitted for publication. Copy on file with authors.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*(2), 175–218.

Greenhow, C., & Robelia, E. (2009). Old communication, new literacies: Social network sites as social learning resources*. Journal of Computer-Mediated Communication, 14*(4), 1130–1161.

Janssen, J., Kirschner, F., Erkens, G., Kirschnker, P. A., & Paas, F. (2010). Making the black box of collaborative learning transparent: Combining process-oriented and cognitive load approaches. *Educational Psychology Review, 22*, 139-154.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research. *Computers in Human Behavior, 19,* 335-353.

Linn, M.C., Clark, D., & Slotta, J.D. (2002) WISE design for knowledge integration. *Science Education, 87*(4), 517-538.

Morris, M., Ryall, K., Shen, C., Forlines, C., & Vernier, F. (2004). Beyond "social protocols": multi-user coordination policies for co-located groupware. *Proceedings of the 2004 ACM conference on Computer Supported Cooperative Work* (*CSCW '04*), Chicago, IL (pp. 262-265),.New York, NY, USA: ACM.

O'Reilly, T. (2007). What is web 2.0: Design patterns and business models for the next generation of software. *Communications & Strategies, 65*, 17–37.

Puntambekar, S. (2006). Analyzing collaborative interactions: divergence, shared understanding and construction of knowledge. *Computers & Education, 47*(3), 332-351.

Rick, J., & Guzdial, M. (2006). Situating CoWeb: a scholarship of application. *International Journal of Computer-Supported Collaborative Learning*, *1*(1), 89–115.

Scardamalia, M. (2004). CSILE/Knowledge Forum®. In *Education and technology: An encyclopedia* (pp. 183–192). Santa Barbara, CA: ABC-CLIO

Scardamalia, M. & Bereiter, C. (1996). Computer support for knowledge-building communities. In T. Koschmann (Eds.), *CSCL: Theory and practice of an emerging paradigm* (pp. 249-268). Mahwah, NJ: Lawrence Erlbaum Associates

Shirky, C. (2011). *Cognitive surplus: How technology makes consumers into collaborators*. New York, NY: Penguin Press.

Stahl, G. (2006). Sustaining group cognition in a math chat environment. *Research and Practice in Technology Enhanced Learning*, *01*(02), 85–113.

Yin, R. K. (2003). *Case study research: Design and methods*. Applied social research methods series (Vol. 5). Thousand Oaks, CA: SAG.

Acknowledgments

We would like to thank the participants in our Kitchen Chemistry program, as well as supporting faculty and parents at the school in which Kitchen Chemistry was held. Additionally, we would like to thank Kidsteam researchers Allison Druin, Mona Leigh Guha, Gregory Walsh, Elizabeth Foss, Evan Golub, and KidsTeam child designers for partnering with us to design the SINQ app. Furthermore, we acknowledge Janet Kolodner and Christina Gardner for their work in developing the Kitchen Chemistry program. Finally, we thank the Computing Innovations Fellows Program for supporting this research.