The 3R Orchestration Cycle:
Fostering Multi-Modal Inquiry Discourse
in a Scaffolded Inquiry Environment

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Abstract: This paper reports on second and third iteration classroom trials of Common Knowledge (CK2 and CK3 respectively) – a pedagogical and technological innovation that supports teacher orchestration of inquiry discourse occurring in the digital CK environment and face-to-face in the classroom. CK facilitated the scaffolding of grade 5/6 students through phases of collaborative biodiversity (CK2) and astronomy (CK3) inquiry. Using tablets, students contributed to a community knowledge base that was publicly displayed on an interactive whiteboard (IWB). The IWB visualized the community's idea flow, enabling learners to sort their ideas along socially-negotiated categories. Inquiry work done in the CK environment affected the knowledge work done in the face-to-face classroom discussions, and vice versa. We observed that teachers used an orchestration cycle of Reflect-Refocus-Release (3R) as a means of managing this blended learning environment. A comparison of teachers' Reflect discourse structures between both iterations indicate such patterns vary with inquiry task demands.

Keywords: orchestration, discourse, inquiry, collaboration, blended learning environment

Introduction and objectives

Advances in computer supported collaborative learning (CSCL) research have yielded technologies where discourse plays a fundamental role of collaborative knowledge building (e.g., Group Scribbles - Roschelle et al., 2007; ConcertChat - Stahl, 2006). Some CSCL environments have used the technology to "script" collaborative problem solving processes within a community (e.g., CollPad - Nussbaum et al., 2009). Other CSCL environments scaffold online discourse and add an element of crowd sourcing (e.g., "likes" for promising threads; PeppeR - Hewitt et al., 2013) for collaborative learning in a face-to-face (F2F) environment (e.g., InterLACE - Coopey et al., 2013; Moodle - Dougiamas & Taylor, 2003; Knowledge Forum - Scardamalia, 2002). Inquiry discourse can be viewed as a social process of meaning construction (Vygotsky, 1962). Such discourse may include argumentation (Kuhn, 1993), theory-building (Bereiter & Scardamalia, 2012), or explanation building (Sandoval & Reiser, 2004). However, the underlying goal of all these environments is the pursuit of deeper understanding and the epistemic practice of science (Nickerson, 1985).

In learning environments that aim to engage students as a knowledge community in collective inquiry toward the production of knowledge as a product, there is typically a heavy reliance on teacher-guided oral community discourse (Slotta & Najafi, 2010). However, this places a serious burden on teachers to orchestrate inquiry in blended learning environments (i.e. F2F classrooms incorporating computer-mediated activities), as they must continuously traverse online and F2F environments to guide discourse towards productive paths of inquiry. If technology for guiding inquiry and discourse is to minimize teachers' "orchestration load" (Dillenbourg, 2012), we must first understand how teachers guide such multi-modal inquiry and discourse, in order to design scaffolding technology to relieve some of their orchestration load. Hence, there remains a need for research of discourse and activity sequences in technology-mediated inquiry environments. This study seeks to identify *patterns of teacher orchestration and forms of teacher-guided inquiry discourse in the successful application of community note-sharing environments in elementary classrooms.*

We continue to innovate on the development of Common Knowledge (CK) – a content-agnostic pedagogical and technological note-sharing application for collaborative inquiry. Using tablets, students contribute to a community knowledge base that is publicly visible from the IWB. This interactive display visualizes the community's idea flow and enables learners to sort their ideas by topic. Building on the

affordances of the second iteration (CK2), the third iteration (CK3) incorporates an inquiry script, scaffolding the community through phases of science inquiry: Brainstorm, Propose, and Investigate. Students *brainstorm* questions and theories, by contributing Brainstorm notes; students then *propose* research trajectories and design experiments to test their theories, by contributing Proposal notes. Such contributions inform subsequent work in fluid interest groups (each supported by an interest-specific shared interactive display), in which students *investigate* the proposed research, sharing findings via Report notes, and making inter-group connections. This paper will report on CK2 and CK3 classroom trials, presenting an observed Reflect-Refocus-Release (3R) cycle of teacher orchestration that occurred across multiple iteration enactments, and a comparison of teacher discourse structures occurring in the Reflect orchestration phase.

Theoretical perspective

Knowledge building

Our research is grounded in the theoretical tradition of classrooms as Knowledge Communities, where community members value a diversity of expertise, metacognitive awareness, a common goal of advancing the collective knowledge, and a means by which to share learning (Bielaczyc & Collins, 1999). Knowledge Building is one of the most prominent examples of the knowledge community approach and has been advanced as a powerful way of learning (Bielaczyck, 2011; Hmelo-Silver & Barrows, 2008; Scardamalia & Bereiter, 1996). Students engage as a knowledge community in collaborative inquiry discourse with peers and teachers to improve emergent understanding, and are scaffolded by a CSCL environment such as Knowledge Forum (Scardamalia, 2002).

Knowledge community and inquiry

The Knowledge Community and Inquiry (KCI - Slotta & Najafi, 2010; Slotta & Peters, 2008) approach has been advanced as a more accessible model for real-world classrooms and their inevitable "extrinsic constraints" (Dillenbourg et al., 2012), such as time, curriculum relevance, and assessment. In KCI, students are scaffolded to work as a knowledge community in building a collective knowledge base, which becomes a resource for subsequent scaffolded inquiry activities, targeting specific learning goals (Peters & Slotta, 2010; Slotta & Najafi, 2012).

The role of discourse in a knowledge community approach

Language has been shown to be a central mediator of thinking and learning within a knowledge community (Wertsch & Smolka, 1994), as communication with peers and teachers generates new meaning or insight about next steps for inquiry (Sfard, 2007). Reciprocal Teaching (Palincsar & Brown, 1984) was conceived as a transitional discourse structure to help students progress from teacher-mediated dialogue to independent small group discussion, with a gradual fading of teacher direction and structure. Bereiter and Scardamalia (2008) define five levels of classroom dialogue, varying in their levels of structure and teacher directedness.

O'Connor and Michaels' (1996) analysis of "revoicing" – the oral or written re-phrasing of a student's contribution by another participant (often the teacher) – describes how teachers orchestrate group lessons through language socialization into intellectual practices, by positioning students in relation to each other and aligning them with the academic content at hand. Teacher "revoicing" of student comments can advance discussion by (1) using student contributions to introduce new ideas or terminology, (2) reframing student contributions to steer the discussion in toward a productive direction, (3) positioning a student in relation to the argument by attributing his or her comment to a stance, or (4) creating alignments and oppositions within an argument – thereby positioning students in relation to their peers (O'Connor & Michaels, 1996). "Revoicing" thus offers a means for teachers to orchestrate classroom discourse and foster idea growth, reinforcing collective epistemology and guiding inquiry progression.

Scripting and orchestration

Knowledge community approaches typically rely on the teacher to foster community knowledge sharing and collaboration. Yet collaborative learning research has shown that learners need guidance to engage in such "high-level" collaboration processes (Weinberger et al., 2010). To compensate for learners' lack of collaboration skills (i.e. lack of internal collaboration scripts), external collaboration scripts may be used initially and gradually faded as learners develop their collaboration skills internally (Fischer et al., 2012). CK incorporates collaboration scripting (involving elements of crowd sourcing and interest-based social groupings) and an inquiry script (comprised of successive inquiry phases) designed to support the community's eventual knowledge convergence. The enactment of even the most thoughtful pedagogical designs, whether facilitated by

technology or not, requires thoughtful management of students, activity, resources, technology, and time – what Dillenbourg contentiously (Roschelle, Dimitriadis, & Hoppe, 2013) redefined as 'orchestration': "how a teacher manages, in real time, multi-layered activities in a multi-constraints context" (Dillenbourg et al., 2012; p.1). Indeed, one CK design objective was to minimize teachers' cognitive load, what Dillenbourg calls "orchestration load" (2012). As an "orchestration tool" (Dillenbourg et al., 2012), the inquiry and collaborative scripts at the heart of CK's technological design and topic-focused visualizations, enable the knowledge community to cope with their incoming ideas arising from all members ostensibly "talking" simultaneously, and offer a technology structure to manage the community's inquiry process.

The study lends new insight into how forms of knowledge building can be integrated into a KCI curriculum and KCI-scripted technology design. It further offers an example of how teachers may orchestrate these to foster collaborative inquiry toward productive trajectories and forms of discourse, by which they facilitate the knowledge community's inquiry progress.

Method

This study is part of a program of design research to investigate theory and practice of the KCI model, and is situated within the broader multi-year "Embedded Phenomena & Inquiry Communities" (EPIC) collaborative research project (Moher & Slotta, 2012). The teachers and the school's vice principal—all co-authors on this paper and masters of Knowledge Building practice—have been included in iterative CK co-design cycles (Roschelle, Penuel, & Shechtman, 2006) since 2011. Data sources from our observations of grade 5/6 classrooms included field notes, video recordings, teacher and student interviews, and data logs of CK discussions. A grounded approach (Glaser & Strauss, 1967) to video coding was used to determine teachers' orchestrational and discursive scaffolds. Participants were two veteran grade 5/6 teachers, 'Brad' and 'Jen', in a private elementary school located in a large Canadian city, with 23 students each (approximately equal numbers of grade 5 and 6 students). By our third iteration of CK, Brad had been teaching for 8 years, and Jen for 5 years. The school has an emphasis on inquiry and Knowledge Building pedagogy.

In enactments of CK2, students were engaged for nine weeks during the fall of 2011 in a biodiversity inquiry curriculum—WallCology Embedded Phenomena— where they were tasked with investigating a virtual "live" ecosystem located "within" their classroom's walls (Moher & Slotta, 2012). CK2 was integrated into the broader suite of WallCology inquiry tools that guided students through six successive content-based inquiry phases, in which they were tasked with determining each species' life cycle, environmental and food preferences, and the ecosystem's food web. Students entered observations and CK notes about the four habitats located within their classroom walls, observed through a "WallScope" (a large monitor) mounted on each wall. In each phase, students could continuously access their peers' CK notes from tablets, as well as compose CK notes, incorporating pre-programmed science content and process keyword tags that were specific to the inquiry phase at hand. Online CK2 discussions were integrated into the inquiry curriculum, with specified discussion goals. Teachers also launched spontaneous CK2 discussions, as they felt were warranted.

CK3 was a content-agnostic standalone application, which closely coupled an inquiry script with a technology script. Knowledge communities were scaffolded through phases of astronomy inquiry, towards knowledge convergence that was connected to teachers' curriculum goals of addressing the topics of gravity, scale, and nested systems. It also aimed to capitalize on the physical classroom layout as an additional dimension of collaboration scripting and collective knowledge mapping. This was a 9-week grade 5/6 Astronomy inquiry progression supported by CK3, and was enacted in the spring of 2013.

To investigate *teachers' orchestration of classroom activity*, the cumulative amount of classroom time teachers allocated to inquiry activity involving CK3 over the 9-week enactments was noted. A grounded approach to video coding of CK2 and CK3 enactments was used, with coarse-grain coding focused on teachers' activity orchestration. Any teacher-guided community oral discussion involving at least one student speaker and lasting for at least one minute, was coded as a community discourse episode ("CDE"). Student-driven activities that involved Common Knowledge were coded as "SD-CK". Video data of two 90-minute CK2 classroom periods and three 90-minute CK3 classroom periods from each teacher were chosen for finer grain coding, based on the richness of CK-driven classroom discourse and opportunities for CK note contributions during the same session. We sought to analyze the class periods with the most uninterrupted usage of CK, in order to capture what might be construed as characteristic inquiry orchestration patterns. Finer grain coding focused on teachers' discourse patterns during CDEs, to *discover possible discourse patterns* emerging from teachers' moves.

Findings and discussion

Teachers' activity orchestration

Video coding of Brad's and Jen's CK2 and CK3 enactments for teacher-guided community discourse episodes ("CDE"), and student-driven activities that involved Common Knowledge ("SD-CK") revealed that students participating in CK3 enactment in both Brad's and Jen's classrooms spent more time in student-driven activities than in teacher-guided activities. This is reversed from the pattern seen in CK2 enactment, where teacher-guided activity was favored (see Figure 1). Jen in particular, showed a dramatic shift in her allocation of classroom time from CK2, when 55% of the time in which CK2 was a focus was given to teacher-guided community discussion episodes (CDE); to CK3, where only 24% was given to CDE. In CK3 enactment, students were given more time to work independently in the CK3 environment, enabling them to reflect more meaningfully (as evidenced by their CK3 notes) on their own CK3 contributions and that of their peers.
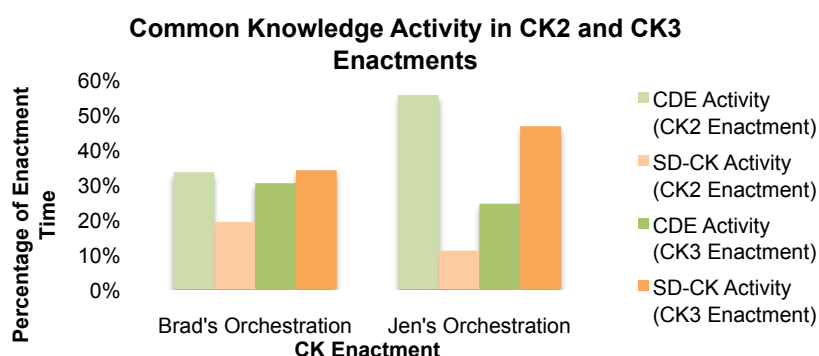

Figure 1. A comparison of teachers' orchestrated time in CK2 and CK3 enactments, spent on community discourse episodes (CDE) and student-driven inquiry in the CK environment (SD-CK).

It is interesting to this study that changes to our script and technology features could induce such a large behavioral shift in classroom discourse structures. One possible explanation for this shift is that CK2 was more content-oriented (i.e., WallCology investigations), while CK3 was more process-oriented (i.e. student-driven astronomy inquiry), with no predetermined content or referent for discourse. As such, discussions during CK2 enactment were more content–oriented, and less process-oriented; whereas discussions during CK3 enactment were more process-focused, looking for patterns and connections within the knowledge base. Furthermore, the student-driven nature of CK3 content resulted in the teacher spending more time in small group interactions with student collaborators working on common inquiry goals. This resulted in more orchestration time given to student-driven inquiry activity in the CK3 environment, and less time given to community reflection discussion.

Qualitative video analysis and closer examination of the sequencing of CDE and SD-CK events for CK2 and CK2 enactments, revealed that teachers guided their communities towards productive inquiry through rounds of CDE in which they scaffolded students to *reflect* upon and discuss their peers' CK3 notes, culminating in teachers' instructions that *refocus* the community's subsequent inquiry activity, whereupon students were *released* to pursue their inquiry trajectories (i.e., SD-CK) – resulting in further note contributions to the community knowledge base. This 3R cycle (Reflect-Refocus-Release) figured prominently in teachers' orchestration of their enactments. Reflective discourse was pivotal in helping students develop awareness of their community's state of knowledge, achieve knowledge convergence, and receive teacher guidance towards productive inquiry.

Figure 2 provides more details about teachers' orchestration of CK3 activity during the three classroom sessions of CK3 enactments that were selected for further analysis. The top level of each teacher's panel (i.e., "# of Notes") presents students' note contribution activity corresponding to SD-CK events. During the three class sessions, Brad's students contributed 21 Brainstorm notes (including Build-on notes from peers), 19 Proposals, and 15 Reports, while Jen's students contributed 64 Brainstorm notes (including Build-ons), 39 Proposals, and 4 Reports. The number of notes shown begins with a non-zero value, as some notes had been contributed in class sessions preceding those that were coded.
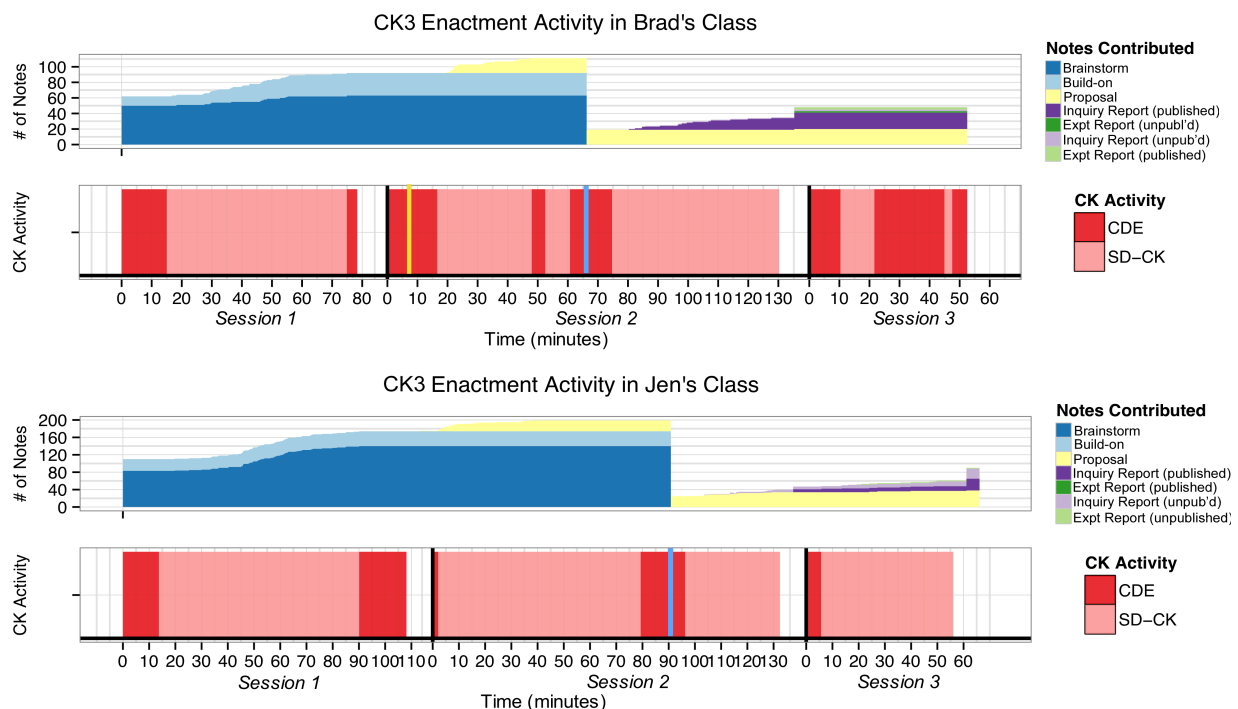
Figure 2. Enactment timeline for Brad's (top) and Jen's (bottom) orchestration of CK3 activity during their three selected class periods of CK3 enactment. The black vertical lines delineate the end of one period and the beginning of the next period. The yellow vertical line marks when Brad initiated the Propose phase of inquiry (Jen initiated the Propose phase in a different session). The blue vertical lines mark when each teacher initiated the Investigate phase of inquiry. For each teacher, the bottom (red/pink) level shows the orchestration sequencing of CK3 activity. The top level shows students' contributions of different types of CK3 notes.

The red/pink "CK Activity" graphs in Figure 2 illustrate teachers' pacing and sequencing of the Reflect (CDE, red) and Release (SD-CK, pink) phases of the 3R orchestration cycle. Students produced knowledge artifacts during the Release phases, in the form of CK3 notes – as can be seen in the increase of notes (see "# of Notes" graphs in Figure 2) during the Release phases. Similar analyses were done on two selected class sessions of each teacher's CK2 enactment, and also showed increases in note contributions during SD-CK (Release) events. For enactments of both iterations, teachers used students' CK notes to launch and guide F2F community discussion during the Reflect phase of their orchestration. Teachers often concluded a discussion with Refocus instructions intended to provide direction to students about strategies to address issues that emerged from that discussion.

Teachers' discourse patterns

The continuous back-and-forth movement between student-driven activities in the CK environment (Release) and community discourse events (Reflect), each informing the other, was guided by teachers' Refocusing instructions. These instructions emerged naturally from student input during Reflection community discussions. A closer examination of teachers' discourse moves during these discussions was done to investigate how they facilitated the discussions towards productive trajectories and guided ensuing student-directed inquiry work for the subsequent Release phase of activity orchestration.

A grounded approach to video coding of teachers' discourse moves during their facilitation of community discourse events (i.e. Reflect phase of orchestration) in their two selected CK2 enactment sessions and their 3 selected CK3 enactment sessions, revealed four orientations of teacher-initiated exchanges: (1) Teacher Reflection (TR), in which the teacher "revoices" or engages in a personal reflection about recent ideas or progress; (2) Individual Student Reflection (IR), in which individual students or groups were posed an inquiry question; (3) Whole Class Reflection (CR), in which the teacher poses a reflection question to the classroom as a whole; and (4) Class Instruction (CI), in which the teacher issued straightforward instructions to the class. Teachers used these orientations to guide community discourse, promote reflection on the community's collective knowledge base, and engage the community in discursive knowledge work.

Since Brad and Jen had similar discourse orientation patterns to each other, in their enactments of both iterations, the distribution of teachers' discourse orientations were collapsed across teachers and a comparison was done between teachers' discourse orientations for CK2 and CK3 enactments (see Figure 3). Notably, teachers placed less emphasis on community reflection (CR) and individual student reflection (IR) in CK3 enactment than they had in CK2 enactments, with increased emphasis on community instruction (CI) and teacher reflection (TR) in CK3 enactment. This shift in teachers' discourse patterns may again be attributed to the differing inquiry task demands between content-focused CK2 and process–focused CK3.

Teachers' Discourse Orientations During Community Discourse Episodes (CDE) in CK2 and CK3 Enactments
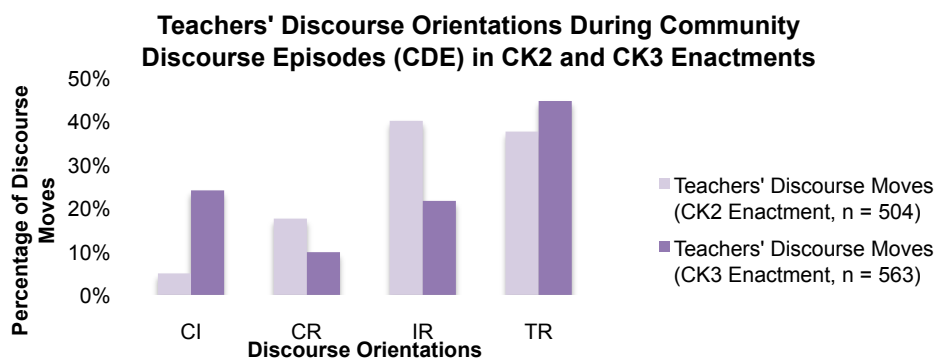

Figure 3. A comparison of teachers' discourse orientations during community discourse episodes (CDE), as a percentage of teachers' total discourse moves, over their selected class periods of CK2 and CK3 enactments. Teachers' discourse orientations: community instruction (CI), community reflection (CR), individual reflection (IR), and teacher reflection (TR).

All coding was done by the first author, with code key refinement done through a process of inter-rater checking with this study's second rater, who independently coded 20% of teachers' video-recorded discourse moves during their selected enactment sessions, for the four discourse orientations (CI, CR, IR, TR). Inter-rater agreement was 94%, and the inter-rater reliability was found to be Cohen's Kappa = 0.91.

Teachers used TR discourse orientations to model their knowledge work processes as they interacted with students' CK note contributions. Such processes may begin with identifying common themes, unique perspectives, and knowledge gaps, then move into relating ideas to prior knowledge or prior experiences, assessing the community's current epistemic approach, and suggesting a new epistemic approach. Teachers also used TR discourse orientations to amplify students' ideas in the public sphere, "revoicing" ideas, sometimes fusing this with their own phrasing toward a purposeful direction and seeking student validation of—or response to—their particular "revoicings". Such discourse moves can be seen as disrupting the traditional teacher-student power dynamic, since the student is now positioned to evaluate what the teacher said. CR and IR orientations were often employed to empower students through role-casting individual students (IR) or the community-at-large (CR) as legitimate participants of inquiry (e.g., questioner, observer, theorizer, inquirer), while simultaneously seeking students' explanations of what they had shared in CK notes or spoken comments. CR and IR orientations were also used, less frequently, to encourage students to verbally build-on an idea, synthesize multiple ideas or multiple CK notes, comment about the current epistemic approach, or suggest a new epistemic approach to pursuing the inquiry.

Conclusions and implications

In a CK-mediated classroom, students engage in collective inquiry in an online notes-based environment and in teacher-guided discussions in the classroom environment. The inquiry work done in one learning environment affects the knowledge work done in the other, and vice versa. We observed that *teachers utilized an orchestration cycle of Reflect-Refocus-Release (3R)* as a means of managing this complex balance. Teachers' refocusing instructions were critical in guiding inquiry work done in the CK environment, and the work done in the student notes was vital to informing teachers' scaffolding of whole class reflections.

An interesting shift in the allocation of instructional time occurred between CK2 and CK3 enactments, evidently as a result of the differing forms of inquiry (and differing technology scripts to support these) in the two enactments. CK2 was integrated into a more content-focused WallCology curriculum progression, with teachers allocating more time for community discussion (i.e., Reflect) and less time for independent student work periods (i.e., Release). CK3 scaffolded students through a more process-focused student-driven inquiry progression, with teachers allocating less time for community discussion, and more time for independent student work periods. This suggests *discourse patterns/structures vary with inquiry task demands*. Perhaps teachers felt

a greater need to guide student inquiry differently in both cases, spending more time in small group interactions during students' work period, to guide the process-focused CK3 enactment.

Teachers' discourse moves during community discourse episodes in all three iterations revealed the presence of *four discourse orientations: class instruction (CI), community reflection (CR), teacher reflection (TR), and individual reflection (IR)*. Once again, there were observed differences in discourse patterns between CK2 and CK3 enactment, in terms of the degree to which the teachers used each of the four orientations. A substantial reduction in the use of IR and CR orientations was seen in CK3 enactment, accompanied by an increase in community instruction (CI) and teacher reflection (TR). These different patterns are also likely a consequence of shifting task demands across the two iterations. Teachers, in their discourse, must move the class through the inquiry script, using the technology environment as an orchestrational tool. Between CK2 and CK3, profound design changes were made to the technology and inquiry script. CK3 shifted away from content-embedded technology features (e.g., pre-programmed keywords related to inquiry phase at hand) and content-driven inquiry script, towards content-agnostic technology features and a process-driven inquiry script. These design shifts clearly impacted the forms of discourse arrived at by the teachers as they followed the pedagogical script.

However, a limitation of CK3's focus on scripted inquiry progression of autonomous student inquiry phases is that it may have hindered the breadth of students' investigations. Teachers did remark about this trade-off, and should be a consideration in any future design efforts.

By engaging students in reflective note-sharing as part of a scripted inquiry progression, we were able to investigate how CK could help students and teachers engage in a Knowledge Community and Inquiry (KCI) approach. By adding CK as an inquiry scaffold, we produced a blended form of learning environment, where individual students develop and share their inquiry work within a common digital repository, motivating teacher-guided discussions, which in turn motivate new, refocused inquiry using CK. The note-sharing system becomes a tool that mediates between the two learning environments: students' collective inquiry done in the digital note-sharing environment and community knowledge work done during teacher-guided classroom discussions. Successful mediation of this blended learning environment entails the agile orchestration of inquiry activity between the online and F2F environments, and strategic guidance of the community toward inquiry progression. Hence the note-sharing system serves a dual purpose: to mediate between inquiry learning environments, and to support teachers' orchestration of the learning progression.

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