Analyzing Equality of Participation in Collaborative Inquiry: Toward a Knowledge Community

Abstract: This paper shares preliminary findings from a designed-based study of the Knowledge Community and Inquiry (KCI) model for secondary science curriculum. We investigate the impact of the model on students' cooperative knowledge construction and their understanding of the science of climate change. Working closely with a science teacher, we co-designed a 10-week curriculum unit with small group and whole class collaborations across two participating classrooms. We present detailed analysis of the wiki content created by two groups of students, revealing a positive correlation between students' contribution to collaborative inquiry activities and their achievements in the curriculum. This finding suggests the need for increased scaffolding to support symmetric participation in collaborative inquiry so that both high and low achieving students benefit from such collaborative science curriculum activities.

Purpose of the Study

Typical classroom instruction in science still focuses on rote learning of content, performance of problem solving, and coverage of standards and expectations (Slotta & Linn, 2009). Several traditions in the Learning Sciences, such as inquiry-based learning (e.g. Krajcik, Blumenfeld, Marx, & Soloway, 2000) and knowledge communities (Brown & Campione, 1994; Scardamalia & Bereiter, 2006), propose pedagogical approaches that would transform teaching and learning in science classrooms. Despite its success in increasing students' understanding of topics, inquiry-based learning still seeks strategies to promote collective knowledge construction within classrooms (Linn, Clark, & Slotta, 2003). By the same token, developing knowledge communities in classrooms has proven difficult due to lack of concrete guidelines for designing collaborative activities, as well as the challenges of bridging small-group collaboration with the wider community knowledge-base, and of sustaining long-term collaborative inquiry (Lehrer & Schauble, 2006).

This study investigates the effectiveness of a new hybrid model of collaborative inquiry situated within a knowledge community that enables students and teachers to engage in inquiry activities that are designed to deeply interconnect with a classroom-constructed knowledge base. To overcome the challenges of developing inquiry-oriented knowledge communities in secondary school science classrooms, the Knowledge Community and Inquiry model (KCI) proposes utilizing collaboration scripts (Kollar, Fischer, & Hesse, 2006) scaffolded by a technology-enhanced environment – in this case, a wiki. The KCI model builds on recent research that integrates structured collaborative patterns to complement collective knowledge construction and inquiry process to alleviate aforementioned challenges and foster inquiry-oriented knowledge communities (Hmelo-Silver & Barrows, 2008).

This research extends prior studies on KCI (Slotta & Peters, 2008) by integrating the model deeply into a grade 9 science curriculum unit concerned with climate change, and by adding a scripted collaborative component to the inquiry activities. The purpose of the larger study (now entering its second year of data collection) is to investigate the effect of the refined KCI model on students' cooperative knowledge construction and deep understanding of climate change concepts. The present paper will examine the quality of knowledge objects constructed by the students and the patterns of students' engagement in collaborative inquiry.

Theoretical Framework

Knowledge Communities

Learning science researchers advocate the notion of "Knowledge Community" to support learning. Of special interest to this research are the conceptual frameworks of Fostering Communities of Learners (FCL; Brown & Campione, 1994) and Knowledge Building Communities (KBC; Scardamalia & Bereiter, 2003) that have been intensively researched in the context of k-12 education. Although the two frameworks differ in their guiding principles, with FCL following a cycle of "research, share and perform" KBC pursuing idea improvement as a product of students' knowledge construction efforts, they can be synthesized along three dimensions.

<u>Distributed cognitive responsibility:</u> Traditional forms of instruction, such as lecture, are not conducive to helping students integrate knowledge for deep understanding of concepts (Brown, 1997). In a knowledge community approach, students become involved in articulating their own learning goals and planning the learning activities. Members of a knowledge community are not only responsible for the quality of their individual learning, but also are held accountable to communicate with other community members to scrutinize the quality of collective knowledge (Bielaczyc & Collins, 1999). Metacognition and reflection serve to increase

students' awareness of how they learn and thereby enable self-reflection, critical inquiry, and flexible application of knowledge in novel situations.

Community knowledge-base: In a knowledge community approach, knowledge sources are no longer limited to the teacher and curriculum materials, but include knowledge artifacts identified or created by the students (Bielaczyc & Collins, 1999). A shared knowledge base promotes a diversity of ideas and facilitates access to those ideas in order to encourage the continued growth of community knowledge (Brown & Campione, 1994; Scardamalia, 2003). Structured collaborative activities intentionally distribute expertise among students, requiring them to negotiate their individual knowledge within collaborative groups and organize their new understandings in a common community knowledge base (Brown & Campione, 1994). Students' contributions to the community knowledge base will survive and be extended only if they are deemed important to the community (Scardamalia, 2003). Thus any artifact produced during such activities should carry the potential to be improved by others.

Pedagogical and technological scaffolds: To help teachers and students achieve the nuanced flow of ideas, activities and discourse within a knowledge community, researchers often introduce specific forms of guidance or scaffolds. These include collaboration scripts technology tools that guide students' knowledge building processes or discourse. In KB, for example, technology serves as a repository of ideas as well as a tool for collaborative knowledge construction (Scardamalia & Bereiter, 1999).

Challenges for Fostering Knowledge Communities in Classrooms

Empirical research provides inconclusive results regarding the viability of the knowledge community approach in classrooms. The few published studies conducted on FCL-inspired classrooms report major challenges regarding instructional design and implementation (Sherin, Mendez, & Louis, 2004). Knowledge community frameworks propose epistemological more than procedural changes to learning and teaching. How will these principle translate into design guidelines for classroom practice? Sustained collaboration between researchers and teachers appears to be one enabling condition. Studies on knowledge building demonstrate the need for such partnerships to focus on principles to guide their design and implantation (Zhang, Scardamalia, Reeve & Messina, 2009). Despite some empirical evidence of effectiveness, knowledge community frameworks have not received widespread popularity among researchers and practitioners. A potential explanation for this limited uptake by the wider community of learning scientists is the high demand of time and human resources that is required for the design, implementation and evaluation of any knowledge community approach.

There is an evident challenge to any application of a knowledge community model in secondary science courses. Knowledge building discourages topic-centered discussions (Bereiter, 2003) in favor of inquiry problems. It requires a long time – potentially up to 6 months – to get the community established sufficiently well that they could identify conceptually inclusive problems that connect multiple topics together Scardamalia (2003). Both of these challenges – the open-ended nature of topics and the time-intensive aspect of community development – are ill suited to secondary science where teachers must make efficient use of curricular time to target a well specified set of science topics. In one of the few published accounts of a KB approach to secondary science (Van Aalst & Chan, 2007) the authors acknowledge making several compromises and falling short of a full implementation of KB.

Considering the challenges that researchers face when studying a knowledge community approach in classrooms, one appealing approach is to develop new models that integrate Web 2.0 technologies with known collaboration scaffolds (Slotta & Peters, 2008). Web 2.0 technologies can provide increased awareness of shared knowledge and help scaffold students in collaboratively constructing new knowledge. This could facilitate the application of a knowledge community approach by researchers in a secondary science context.

Scaffolded Collaborative Inquiry

Inquiry-based learning (IBL) approaches support students in the process of constructing, refining, and applying their understanding of scientific concepts through question-driven, evidence-based, iterative scientific inquiry processes (Krajcik et al., 2000; Linn et al., 2003).

Collaboration is valued in IBL. However, enacting collaborative inquiry within a classroom is challenging, given the longstanding knowledge transmission culture as well as practical limitations such as time and teacher to student ratio (Singer et al., 2000). The quality of collaborative work may suffer without sufficient support, as a result of students' inexperience with fundamental processes such as pooling ideas, distinguishing between valid and invalid ideas, and settling conflicts (Krajcik et al., 2000; Linn & Slotta, 2009).

Technological and pedagogical scaffolds have been used to relieve complexities of collaborative inquiry. For example, Singer et al. (2000) propose that by having small groups of students share their inquiry questions, plans and findings with the whole class, the students can improve the quality of their work.

Different forms of collaborative design patterns that support inquiry have been advanced by researchers partly driven by the increasing interest in fostering communities of inquiry in classroom. These patterns can provide detailed description of the steps required for students to complete a collaborative task, such as reciprocal teaching (Palincsar & Brown, 1984). While this approach suggests great promise, structuring collaborative inquiry in classrooms remains an important topic of research.

Knowledge Community and Inquiry (KCI): A Hybrid Model

Knowledge Community and Inquiry (KCI) is a hybrid pedagogical model that integrates the IBL and knowledge community approaches to facilitate a culture of collective inquiry in classrooms. KCI is being developed to make knowledge communities more accessible to secondary science instruction, including a new role for scaffolded inquiry activities that put the collaborative knowledge-base to use in targeting specific learning goals.

Design principles for KCI science curricula are: (1) *Establishing a shared knowledge-base.* Students identify issues of interest related to the topic of the unit and develop knowledge artifacts—e.g. annotated resources or web pages—that embody the emerging themes to direct subsequent inquiry investigation. (2) *Collaborative inquiry.* Once teachers identify issues deemed important by the class that are suitable for inquiry, they work with researchers and technologists to co-design scripted-inquiry activities that draw upon the shared knowledge-base as a resource for the inquiry activities. Decisions about the kind of scripts to be used in the inquiry activity are made based on the topic of discussion and learning goals identified by the teacher. (3) *Continuing to develop the knowledge-base.* The class is engaged in ongoing knowledge integration, connecting their new ideas and understandings to the existing knowledge-base, which can be used in subsequent inquiry activities. (4) *Technology Scaffolds.* Technology plays an essential role in KCI to help students and teachers visualize collective knowledge, to promote every student's contribution to constructing the shared knowledge-base, and to enable students to easily find and retrieve elements from the knowledge base. (5) *Curriculum Co-design.* Designing curriculum that is accessible to teachers is of prime importance to KCI. Any curriculum design must address learning goals held by the teacher, including school district or government curriculum expectations. Moreover, the design team must accommodate the requirements of conventional assessments and must therefore design activities that yield knowledge artifacts that can be graded for content expectations and that prepare students for existing exams.

Research Questions

The following questions guided this study:

- How will an improved KCI model that relates collaborative inquiry activities to shared knowledge-base impact students' contribution to the classroom knowledge community?
- What are the characteristics of students' contributions to the community knowledge-base?
- How do students' contributions to the knowledge-base relate to their understanding of scientific concepts?
- How do pedagogical and technological scaffolds impact students' contribution to the knowledge-base?

Methods

Design-based methods bring researchers and classroom teachers together to create innovative approaches to problems of practical and theoretical value, allowing them to recursively examine the interactions among multiple design elements to gradually improve the design (Collins, Joseph, & Bielaczyc, 2004). Edelson (2002) identifies two different objectives for design research: Theory testing and theory development. Considering the purpose of this study, which is to understand how a KCI-inspired technology-integrated curriculum can support scientific inquiry while promoting a knowledge community in science classrooms, a design-based method, geared toward theory development, is appropriate.

Participants and Settings

Participants of this research are one science teacher and 42 grade ten students in two classes (A and B). The participating teacher has been actively involved in previous research on the KCI model. Following a co-design approach (Penuel, Roschelle, & Shechtman, 2007), the teacher joined the research team in August 2008 for curriculum design, implementation, and evaluation. These meetings continued throughout the unit to refine materials and address unforeseen situations.

Co-designed curriculum

The curriculum started with an initial knowledge construction activity where students identified useful resources about climate change then annotated and added them under relevant category in a designated wiki page. To promote students' metacognitive awareness of knowledge community, a discussion about "philosophy of science" was also conducted in the first stage of the curriculum. Students then identified important issues related to climate change in Canada that were used to guide small group collaborations. Collaborative inquiry activities included small-group, cross-group, and whole class collaborations. Students formed regional groups to investigate the effects of climate change within each region with regards to three Science dimensions (Greenhouse effect, Weather and wind patterns and Ocean circulation). Within the regional groups, students were assigned to one of the following "specialist roles:" primary industries, secondary industries, environmental activism and tourism industries. For the final project, specialists from all regions joined new advisory groups to synthesize the community's knowledge and provide national guidelines for reducing the adverse affects of global climate change in Canada. All groups were formed across two sessions of the class so that students collaborated with some peers asynchronously. For this iteration, technological infrastructure consisted of a password-protected wiki with sophisticated grouping and permission capabilities, in addition to a collaborative concept mapping software application. Laptops with wireless Internet connections were used for collaborative work. The teacher was highly competent in using technology for teaching.

Data Sources

Multiple data sources were used to capture the richness and complexity of the innovation:

- Contents of student-created wiki pages provided a measure of the quality of students' ideas and their collaborative knowledge construction.
- Pre-post semi-structured interviews with the teacher and selected students provided deeper insight into the teacher's and the students' perspectives.
- Classroom observation field-notes were collected to help identify patterns of practice and to corroborate data about students' engagement in collaborative activities.
- Formal classroom assessments done by the teacher were used as one factor in examining the quality of students work.

Analysis and coding scheme

Comprehensive analysis of data is still underway, and indeed a second iteration of the design study is presently in data collection stages. In this paper, we focus on a portion of findings that examines the effect of this co-designed unit on: a) The symmetry of students' contribution within their small groups (ie, in collaborative inquiry); and b) the quality of students' contribution to the wiki. The objective is to understand how curricular activities promote distributed cognitive responsibility and construction of cohesive and usable shared knowledge. For this purpose, we analyze the progress of two small groups: those who created the Ontario and the Prairies regional wiki pages. For any wiki page analyzed, an elaborate process of evaluating every successive version of the page supports our inferences about collaboration patterns and the growth of ideas within the page. Our unit of analysis was an independently meaningful and cohesive piece of text added to the wiki pages. A unit could vary from one sentence to a multi-sentence paragraph.

<u>Wiki development actions:</u> To measure individual group members' contribution to the wiki pages, we reviewed the actions taken by students while they were editing a page, following a constant comparative method, to identify recurring types of edit actions. This analysis sheds light on the extent to which KCI curriculum promoted distributed cognitive responsibility by revealing whether students go beyond their personal contribution to act on what has been added to their group work by other group members. The resulting categories for coding were: Initiating a new section or major idea (initiate); editing content previously added by self (edit self); editing content previously added by another group member (edit other); making link to another wiki pages (link to page); correcting grammatical mistakes or formatting (minor edits).

<u>Quality of wiki contributions:</u> individual group members' contribution to the wiki pages in progress was coded using a four-point scale: Unelaborated facts, elaborated facts, unelaborated explanations, elaborated explanations (adapted from Hakkarainen, 2003). Another category of "regulatory notes" was added subsequently to capture wiki entries concerned with planning, monitoring, or reflecting on the group's overall progress or specific developments.

Findings and Discussion

Two regional groups, "Ontario" and "Prairies," were selected for this detailed analysis based on the teachers' assessment of their collaborative work. Groups were formed by the teacher and balanced to have both higher and lower achieving students. The mean for the two classes' final unit marking was 71.16 (SD=15.6). The Ontario and Prairies groups were selected as cases because they respectively received lowest and highest marks among seven regional groups. We hypothesized that close examination of these two groups' collaborative inquiry and knowledge construction activity could reveal challenges and advantages in our curriculum design that could guide our design of more coherent collaborative group work and further refine the KCI model.

The Ontario group consisted of six students: Cara, Cheryl, Sam, and Chris (from classroom A) and Sara and Mike (from classroom B). Of these, three scored higher than class mean and three scored lower. The Prairies group had five students: Wendy, Thomas, and Adriana (from classroom A) and Sheila and Mat (from classroom B). Adriana was absent for the final month of the curriculum, which directly affected her contribution to wiki development. We decided to disqualify her contributions from our analysis, which were generally quite minor. In this group, one student scored lower than class mean in the unit and the remaining three scored higher. On average, students in the Prairies group (mean=79.64) received higher final grades than the Ontario group (mean=72.9) in the unit.

Collaborative Knowledge Construction

Using the “wiki development actions” scheme, we coded all versions of the main wiki page for each region, and all the pages linked to each page that had at least one author from the respective group. Each time a student clicked on the “edit” button, this was counted as one edit session. The total number of such edits was tallied as “Total Page Edit” score. Note that it was possible that during and edit session a student took several actions. Students’ individual scores and group means for each item in the coding scheme were then calculated. Figure 1 shows the distribution of edit actions among students from the two groups.

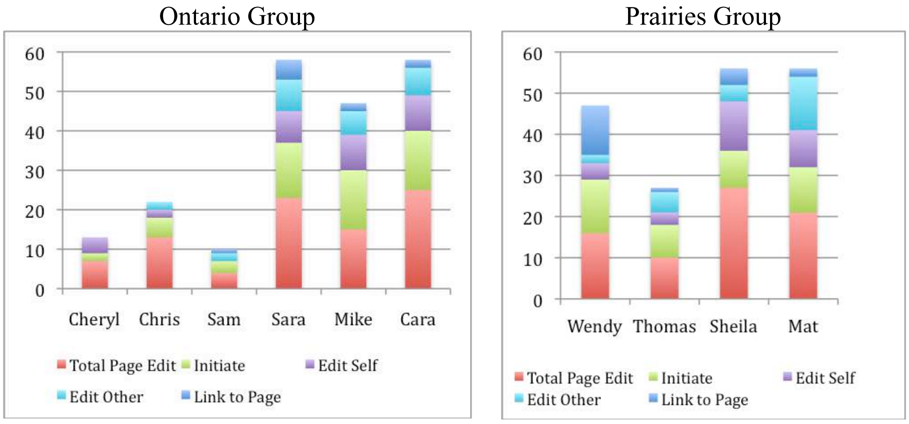

Figure 1. Students’ individual scores for “wiki development actions” in Ontario and Prairies groups

The Ontario group was observed by one of the authors throughout the unit implementation. In classroom A, Cara took a leading role, dividing the work among group members. She also took on a high proportion of the work, making 25% of the edits herself (in group size of 6). In classroom B, Mike and Sara made close to the same number of edits, but unlike the classroom A students who often communicated about their collaborations, Mike and Sara only briefly discussed their collaboration in the beginning of the unit, then worked independently afterwards. Sam had the lowest “Total Page Edit” count from the Ontario group. He was present in all group work sessions, and often engaged his group members in relevant discussions. However, Sam typically only searched for information or edited the wiki when he was asked to do so by other group members.

The Prairies group, although not directly observed, demonstrated a rather more evenly distributed participation in wiki development actions. As we will discuss in the following section of Findings, this group took a more calculated approach to planning and monitoring their collaborative work.

To examine the overall performance of the two groups regarding wiki development, we compared the mean score for each action, as illustrated in Figure 2. The Prairies group showed overall higher means in all wiki development actions. Moreover, students in both groups were more likely to initiate new section of text than to edit the existing material added by other group members or linking relevant pages to their wiki page. Figure 2 shows numerical values of means for comparison. These differences were not statistically significant, presumably due to small group sizes.

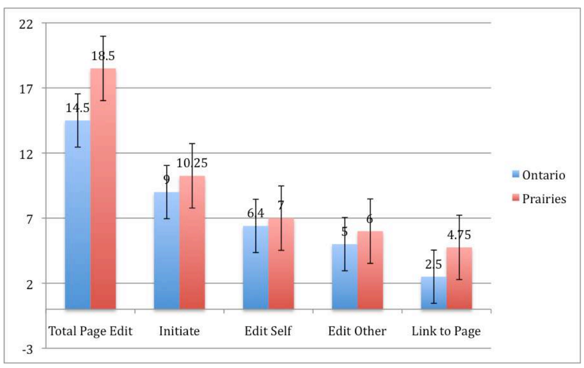

Figure 2. Comparing the means of wiki development actions for Ontario and Prairies groups

Of great interest to this research was the impact of the co-designed curriculum on students’ learning. Of the four wiki development actions two provided some measure of students’ progressively developing the wiki as a collectively owned artifact rather than adding independent chunks of text to it: Edit Other and Link to Page. We thus calculated a “Collaborative Knowledge Construction” score for each student by adding up her/his “Edit Other” and “Link to Page” scores. A correlation coefficient of 0.83 (Figure 3) suggested a strong positive relation between students' Collaborative Knowledge Construction score and their final grade in the climate change unit.

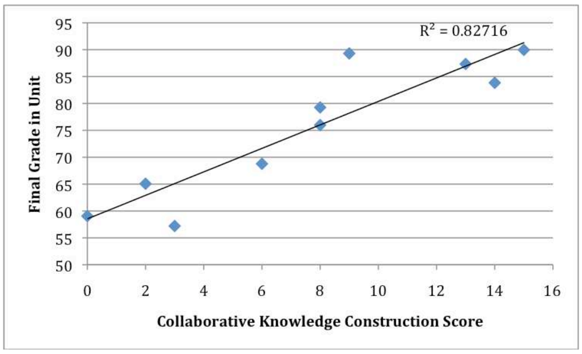

Figure 3. Relation between students' collaborative knowledge construction score in Ontario and Prairies group with their final grade in the unit

Cohesiveness of co-constructed knowledge objects

To cover the scientific issues that needed to be addressed in the inquiry activity, students took a divide and conquer approach to group work. Since the wiki platform we used did not allow for concurrent edits, students decided to create sub-pages to elaborate on their chosen part of the activity. We were interested to know if the students finally integrated their knowledge into a cohesive final report.

Content analysis of the wiki pages revealed that students in Ontario group occasionally ignored existing wiki contents and added somewhat repetitive content to selected pages. For example Sara and Mike added the following sentences to one wiki page:

> "Ontario is Canada's biggest polluter. Over half of Canada's population lives in Ontario, accounting for more waste products and pollutant." (Added by Mike on Dec 18 2008)
> "Ontario has the largest population in Canada, and thus Ontario's GHG emissions will be the highest." (Added by Sara on Jan 8 2009)

Mike's entry was a standalone paragraph on top of the page about "Climate Change Issues" and by the final version of the page this paragraph was redundant. Sara's entry was an introduction into a section on "Carbon Emissions" and was well connected to the rest of the section. Nevertheless, the first entry was never deleted or merged with relevant content to make the page more cohesive and less disconnected.

We also noticed contradictory wiki entries in Ontario group. Factors that impacted the amount of released green house gases were discussed in different pages and by different students. The discussion about this issue started by Chris in the main page where initially green house gases were a sub-section of the main page"

> Chris : Only about 29% of Ontario's energy is taken from fossil fuel sources- the rest is nuclear and hydroelectric (as Ontario is full of rivers that are used for hydroelectric energy)."

Meanwhile, Sara took the responsibility for developing the "Ontario Greenhouse Gases" page by turning the sub-section heading into a new page which included the following entry related to hydroelectric power:

> "Sarah : "Contrary to popular belief, hydroelectric power may sometimes have more GHG emissions than the use of fossil fuels."

The link to this page was directly located above Chris' contribution on December 18 2008. Later, Chris added another entry right under his December 18 2009 entry:

> Chris "Since hydroelectricity generates very little air pollution, greenhouse cases in Ontario are very rarely from power generation "

Although his contribution fell under the green houses gases topic, he did not add it to the "Ontario Greenhouse Gases" page. We assume that Chris did not read this page, otherwise he would have noticed the apparent contradiction between Sara's and his own contributions and the two of them would resolve it with more detailed evidence.

In the Prairies group, students showed higher awareness of their shared content. They often communicated with each other about their contributions through meta-comments. For example in one occasion Mat copied Thomas' contribution to its relevant sub-page, "Greenhouse Gases", edited it to decrease the redundancy, and weaved it into his own sentences previously added to that page. However he did not delete the text on the main page that was added by Thomas. Mat also left a comment on the main Prairies wiki page:

> Matt: "I put it in the green house gases page and split up your points into jot note form, and got rid of some that I've already added there"

An overall comparison of the two series of wiki pages developed by Prairies and Ontario students revealed a lack of cohesiveness where contents were compartmentalized into subpages without being outlined and summarized in an introduction or a summary section. This could be a flaw of our curriculum design, as we did not require the students to synthesize their wiki work as the collaborative activity concluded. It could be inferred that students closely followed the instruction given to them, which did not directly asked for a cohesive presentation of collected information.

Quality of contributions

Wiki pages of Ontario group contained more content than those of Prairies group. This could be attributed to the fact that there were more students in the Ontario group. Table 1 shows the quality of students' individual contributions to Prairies and Ontario wiki pages. Students in the Prairies group made extensive use of regulatory notes to communicate division of labor and state of work among themselves. In the Ontario group, on the other hand, regulatory notes were used only in one occasion to ask for all group members to work harder.

Table1. Quality of students' individual contributions to Prairies and Ontario wiki pages

		Unelaborated Fact	Elaborated Fact	Unelaborated Explanation	Elaborated Explanation	Regulatory Notes
Prairies Group	Wendy	7	6	6	2	2
	Thomas	6	4	4	1	6
	Sheila	9	1		1	2
	Mat	14	6	19	9	1
Ontario Group	Sara	12	10	9	6	3
	Mike	19	9	10	10	2
	Chris	2	4	2	1	0
	Sam	3	6	2	0	1
	Cara	7	8	11	9	0
	Cheryl	8	10	4	0	0

An "overall quality score" was calculated for each individual by adding the scores s/he obtained in each of the five categories of content quality. The relation between overall quality scores and final unit grades also resulted in a positive correlation with a coefficient of 0.72 suggesting that students whose wiki entries are more elaborated are likely to achieve higher marks in the unit.

Conclusion and Significance

In this paper, we shared our interim findings regarding symmetric participation in collective inquiry from the first iteration of a design-based research that examines a hybrid KCI model. This new model encourages even distribution of cognitive responsibility towards building a deep collective understanding of science topics and aspires that students would benefit from each other's contributions to the shared knowledge. Findings shared here, will guide our curriculum design efforts for subsequent iteration of the study in 209-2010.

From the beginning, we expected to observe non-symmetric participation in the inquiry activities both in small group and in whole-class settings. It was our intention, thus, to study the patterns of participation in-situ and design appropriate technological and pedagogical scaffolds to support collaborative activities that maximize the benefits that a knowledge community can offer for all students. Using a wiki as collaboration venue allowed us to study and analyze the process of developing a shared knowledge base through inquiry by disclosing individual student's patterns of participation and their contributions to the final group product.

Careful examination of wiki development actions revealed that students in both groups were more likely to initiate semantically and conceptually new section than to edit the existing material or linking relevant pages to their wiki page (refer to figure for numerical value of means). Upon examining the assessment rubric given to students for their group work, we realized that the students were not explicitly encouraged to act on material added by their group members. A level 4 group contribution was described as "….work in class built on and extended on previous material on wiki" and "material added improved wiki". Yet known characteristics of knowledge communities require students not only to focus on the quality of their individual contributions but also monitor and act on material added by other group members. For these students it was their first experience to make a shared wiki page. "Edit Other" and "Link to Page" wiki development actions in Prairies group showed higher mean which could be due to Prairies students' self-realization that a contribution made to a shared wiki became the intellectual property of all group members. This remains only as speculation as we did not probe these students motivation for group work.

Our findings suggest that students need to be supported in understanding inquiry processes and in actively participating in a collaborative activity since uneven participation may lead to achievement differences. For our next iteration, we are proposing to include two kinds of scaffolds: A reflective self-assessment (e.g. White & Frederickson, 1998), both for small groups and for individuals, to assist students in explicitly monitoring and improving their participation in co-constructing a shared knowledge base; and a participation gauge scaffold to visualize contribution level per student.

Further analysis of the current data will look into the connections that students made between among knowledge artifacts shared by the class.

Scientific Significance

Developing knowledge communities in classrooms has proved difficult (Lehrer & Schauble, 2006) and inquiry-based learning approaches still seek strategies to promote collective knowledge construction within classrooms (Linn, Clark, & Slotta, 2003). We build on recent research that integrates structured collaborative patterns to complement collective knowledge construction and inquiry process to alleviate these challenges (Hmelo-Silver & Barrows, 2008).

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