Exploring Group-Level Epistemic Cognitions within a Knowledge Community and Inquiry Curriculum for Secondary Science

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Abstract: This paper explores Epistemic Cognition (EC) at the collective level within the context of an inquiry curriculum for high school biology. The "EvoRoom" curriculum was 10 weeks in duration, with two major units in evolution and biodiversity as well as a rich media "immersive simulation" activity and a field trip to a local zoo. All activities were designed according to the Knowledge Community and Inquiry (KCI) model, which guides the design of collective inquiry curricula where students make progress as a knowledge community with explicit connections to learning expectations. The paper applies Chinn's EC framework to the design and enactment of EvoRoom and, by extension, to the KCI model. Findings reveal a shift in students' perceptions of "sources of knowledge," however students' "justification of knowledge" was seen to be compromised in cases where students satisficed their original epistemic stance in favor of group consensus.

Introduction

Substantial research has investigated the use of technology enhanced learning environments to support collective inquiry – a form of learning in which students work together as an entire class to create and advance knowledge. For example, Scardamalia and Bereiter (2006) have advanced a theoretical perspective of knowledge building, employing an innovative technology environment called "Knowledge Forum" where students contribute and edit inquiry notes. Other researchers have explored various forms of online discussion tools (e.g. Hmelo Silver, 2010), wiki-based environments (e.g. Peters & Slotta, 2010; Najafi, Zhao & Slotta, 2011) and handheld data collection activities (e.g. Metcalf *et al.*, 2010) in exploring different aspects of students' learning and engagement in collective inquiry.

One aspect of collective inquiry that has not yet received much study is that concerned with students' epistemological knowledge – their beliefs about knowledge and learning, and how those beliefs influence their participation in the curriculum activities. Substantial research has addressed this topic for student inquiry in the wider area of computer supported collaborative learning, where small groups or individuals engage in structured inquiry tasks. For example, several lines of work have examined students' beliefs about the nature of science, and science learning (Lin *et al*, 2013) or the students' understanding of collaboration (Najafi & Slotta, 2010). However not much attention has been given to the collective aspects of epistemology. It is important to study how students' epistemic cognition influences collective inquiry. For example, if students have little experience learning as a community, or if their understandings about learning are not aligned with those of the designed curriculum (e.g. if they are expecting to learn content with the aim of individual achievement), then the outcome of the enacted curriculum may diverge widely from what was intended. Thus, an understanding of epistemic cognition in relation to collective inquiry is vital to our theoretical models, as well as to our design of curriculum and technology environments

Drawing upon the theoretical framework for epistemic cognition, developed by Chinn *et al*. (2011), the present study is guided by the following research questions:

1. How does the design of collaborative inquiry activities affect the ways in which knowledge is justified and shared within a knowledge community?
2. How are students' epistemic stances influenced by the nature of the collective inquiry design?

Theoretical Foundations

"Epistemic cognition" (EC) is a term used to describe any explicit or tacit cognitions that pertain to epistemological matters, such as knowledge, beliefs, truth, sources, justification, evidence, understanding, and explanation (Chinn *et al*, 2011). A number of studies have shown that students' epistemic beliefs are an important predictor of achievement in a variety of learning domains, including information processing (Garner and Alexander, 1994), reading comprehension (Rukavina & Daneman, 1996), test performance (Schommer *et al*, 1992), argumentation (Kuhn, 1991), and the ability to synthesize information from multiple sources (Strømsø and Bråten, 2009). Other studies have revealed the role of epistemic beliefs in affecting chosen learning strategies (Ryan, 1984; Schommer *et al*, 1992), motivation and behaviour (Pintrich *et al*, 1993), and attitudes such as learned helplessness (Qian and Alvermann, 1995). In the domain of school science, Windschitl and

Andre (1998) demonstrated that students with more sophisticated epistemic beliefs (e.g. the belief that knowledge is complex, cumulative, and context-dependent) exhibited greater learning gains when engaged with constructivist pedagogies compared to individuals with less sophisticated beliefs (e.g. the belief that knowledge is simple, quick, and certain). Kardash And Scholes (1996) revealed that students' beliefs about the certainty of knowledge affected the ways they handled and presented contradictory evidence in scientific research, and Qian and Alvernann (1995) further showed that students' beliefs about the simplicity and certainty of knowledge impacted the levels of conceptual change they experienced in school science. It is therefore important to consider students' epistemic beliefs and their interaction with learning when developing theoretical models of learning or specific curricular interventions.

Several scholars have attempted to identify specific dimensions of epistemic cognition to provide general models or frameworks (see, for example, Perry, 1970; Schommer, 1990, 1993; Hofer and Pintrich, 1997). In 2011, Chinn, Buckland and Samarapungavan extended the work of Hofer and Pintrich (1997) by developing an expanded framework for epistemic cognition. Their model included the addition of several new components and subcomponents of EC, as well as the specification of a finer grain size of cognitions within each of these dimensions in order to account for contextual and situational differences in learning processes. The five dimensions of Chinn *et al.*'s 2011 EC framework are:

1. Epistemic aims and epistemic value
2. Structure of knowledge and other epistemic achievements
3. Sources and justification of knowledge and related epistemic stances
4. Epistemic virtues and vices
5. Reliable and unreliable processes for achieving epistemic aims

Chinn *et al*. (2011) recognize that their description of this EC framework maintains a focus on individual cognitions, and the authors further suggest that an opportunity exists for future research to explore these cognitions at the level of groups, which would include students engaged in collective inquiry within a constructivist learning environment. To this end, this paper explores one of the above dimensions, "sources and justification of knowledge and related epistemic stances," in relation to an innovative pedagogical model for collaborative learning in secondary science called "Knowledge Community and Inquiry" (KCI).

As defined by Slotta and Najafi (2010), a knowledge community is one where members (a) collectively develop a shared knowledge base (b) establish characteristic practices for knowledge creation or advancement, and (c) share in discourse for idea sharing, critique and improvement. From an epistemological perspective, the knowledge community approach represents a key shift from the notion of self-as-learner, where an individual is potentially in competition with peers, to one of collaboration and cooperation in which shared knowledge advancement is favored over individual gains. In the context of K-12 classrooms, two widely researched examples of the knowledge community approach are Fostering Communities of Learners (FCL) (Brown & Campione, 1996), and Knowledge Building (Scardamalia & Bereiter, 2006). Although both of these examples have been implemented in K-12 contexts, current school structures and content-heavy curriculum demands can often make these approaches inaccessible to course instructors – particularly at the secondary level, and particularly in content-heavy domains like science. Knowledge Community and Inquiry (KCI) was developed for secondary science as a means of blending the core philosophies of the knowledge building approach with the structural and scripted affordances of scaffolded inquiry (Slotta & Peters, 2008; Slotta & Najafi, 2012). The KCI model includes five major principles, each including a set of epistemological commitments, pedagogical affordances, and technology elements. Together, these guide the creation of inquiry activities, peer interactions and exchange, and cooperative knowledge construction (Slotta et al, 2013).

Until the present study, the epistemic elements of KCI had not been explicitly tested or evaluated. To assess students' epistemic cognitions within KCI, we first evaluated the design of a KCI biology curriculum unit in terms of its epistemic elements, which was done by evaluating the design in terms of the stated epistemic commitments of KCI. We then then evaluated the enactment of the curriculum in terms of actual epistemic cognitions observed in student interactions. The curriculum was a ten-week Grade 11 Biology unit that met the Ontario Ministry requirements for evolution and biodiversity and included activities that were situated in part within a unique immersive environment called "EvoRoom" (Lui & Slotta, 2012). It should be noted that while the KCI model served as an important referent and guide for design decisions, the design of the EvoRoom curriculum was not explicitly concerned with the role of epistemic cognition within KCI. While such elements are essential to the KCI model, they were not at the forefront of concern for the EvoRoom research project, which was focused on designing activity sequences that engaged students with the relevant biology content, as well as a collective immersive simulation environment (Lui & Slotta, 2013). The present research examines the role of epistemic cognition within the EvoRoom curriculum design by taking an 'epistemological pass' at the most recent design iteration. As noted above, this paper presents the findings for one of Chinn *et al*'s (2011) dimensions of EC, "sources and justification of knowledge and related epistemic stances."

Methodology

Research Setting and Design Considerations

The term 'EvoRoom' refers to a 10-week multi-locational curriculum, but also to an actual room that was constructed using smart classroom technologies to provide an immersive simulated rainforest environment. Students' movements and interactions within this smart classroom environment – where they go in the room, and with whom – are carefully orchestrated and dependent upon real-time observations that students make using tablet computers. The broader 10-week curriculum was designed to fulfill the requirements for evolution and biodiversity in Grade 11 Biology. At the time of this study, the EvoRoom curriculum was undergoing its second design iteration. The curriculum design included activities across a number of different contexts, including at home, within the students' regular classroom, the smart classroom, and on a field trip to the local zoo. The main components of the EvoRoom curriculum were organized around the iterative use of an online portal that served as a knowledge base for the community. Periodic inquiry and knowledge construction activities were blended with traditional classroom lectures in the following sequence:

1. Pre-Activity: Epistemic Orientation (Week 0)
2. Online Learning Portfolio/Knowledge construction (Ongoing)
3. EvoRoom Evolution Activity (Week 2)
4. Zoo Field Trip Activity (Week 8)
5. EvoRoom Biodiversity Activity (Week 10)

This paper will focus on the Zoo Field Trip Activity and the EvoRoom Biodiversity Activity. These two activities were chosen as the focus of this study because they employed the same technology platform, Zydeco, to support student inquiry (Kuhn et al., 2010). However these two activities were quite distinct, in terms of their epistemic nature (i.e. their purpose within the knowledge community) and use of collaborations. In regard to the Chinn et al's (2011) "justification of knowledge" dimension, these affordances were directly linked to the design of the Zydeco environment, which was developed by another research team with the aim of supporting evidence-based justifications (Zhang & Quintana, 2012). Hence, KCI might not, on the basis of its own principles, have emphasized such justificatory elements, but its choice of Zydeco as an observational data collection environment enabled this form of EC to be prominent within the enactment.

Figure 1. *Top-left*: Students using Zydeco to collect data within the EvoRoom smart classroom; *Bottom-left*: Zydeco data collection screen used by students to collect and tag multimodal data artifacts (e.g. text notes, photos, video notes, audio notes) and contribute them to a shared evidence base; *Right*: Zydeco explanation screen where students generated knowledge claims and supported them using both evidential justification (i.e. artifacts from the shared evidence base) and non-evidential justification (i.e. reasoning).

Co-Design Team

In order to ensure that the curriculum design (i.e., all activities, tools, materials and interactions) was suitable for high school biology, a co-design approach was used (Roschelle, Penuel & Shechtman, 2006). The co-design team consisted of three researchers (two graduate students and one faculty member), three programmers, and the classroom teacher. Throughout the EvoRoom design process, the teacher was highly involved in the development of the orchestrational scripts and technology elements that went into the design. The teacher met weekly with two researchers over a two-year period, providing valuable feedback with regards to tool development and the overall curricular goals for the evolution and biodiversity units.

Participants

The participants for the current design iteration consisted of two sections of Grade 11 Biology (n=56) from a high-achieving secondary school within a large and ethnically diverse urban setting.

Data Sources

Data sources for both the Zoo Field Trip Activity and the EvoRoom Biodiversity Activity included students' digital learning artifacts contributed through the Zydeco platform, as well as researcher observations and field notes from both activities. Additionally, an open-ended survey was administered to students both before and after the full 10-week EvoRoom curriculum unit, with two items pertaining to sources and justification of knowledge.

Zoo Field Trip Activity Sequence

The zoo field trip was situated between the two immersive experiences in the EvoRoom smart classroom. Prior to the actual field trip, students were given a full period of training on how to use the mobile app Zydeco (Cahill et al., 2010; Kuhn et al., 2010), which was used to collect evidence and observations whilst in the field at the zoo. On the day of the zoo field trip, students were divided into groups of three or four, and each group was given two mobile devices: an iPod touch and an iPad or iPad mini. It should be noted that all sections of Grade 11 Biology – including course sections outside of the sample group – participated in this mobile activity and used Zydeco to contribute evidence to the shared knowledge base.

At the zoo, groups were assigned to a particular species group (e.g. birds, fish, primates, reptiles and amphibians, plants and insects, and other mammals), as well as a designated geographic region of the zoo (e.g. African rainforest, African savanna, Australasia, Indomalaya, Eurasia, and Americas). Their task was to collect evidence, using a variety of multimodal formats (e.g. text notes, audio notes, video notes, photographs), in order to take a position on three issues: 1) the unifying principles underlying biodiversity; 2) human impacts on biodiversity, and 3) what makes an effective educational exhibit. The data from all groups was pooled into a shared evidence base. Students returned to school for the final period and worked in the computer lab using the Zydeco web platform. Using a 'claim–evidence–reasoning' structure, students had the opportunity to draw upon the full set of evidence gathered by their peers from the zoo in order to generate and support their knowledge claims. Students were given one week to complete this individual, summative assignment.

EvoRoom Biodiversity Activity Sequence

During the final week of the EvoRoom curriculum, students participated in a second activity within the smart classroom. Students were assigned to one of four sessions (A to D) in the EvoRoom, and each session consisted of four groups of approximately three or four students. Leading up to this activity, students had learned about biodiversity throughout their regular classroom activities, and groups were asked to make predictions on the online learning portfolio as to how their assigned climatic 'scenario' would impact biodiversity (e.g. high temperature, low temperature, earthquake, tsunami, high rainfall, low rainfall, high temperature, low temperature). When students entered the smart classroom, the screens around the room depicted the present-day Borneo-Sumatran rainforest. After making some initial observations, each of the four walls was transformed to represent one of the climatic scenarios that had been assigned. Within their groups, students used the mobile app Zydeco to collect evidence from each of the four walls in order to identify which rainforest best represented their assigned scenario. The multimodal evidence collected using Zydeco was tagged and aggregated in real-time on the front IWB. The resulting aggregate of evidence served as a reference for a full-class discussion, facilitated by the teacher, and provided visual clues as to which scenario was depicted by which station.

Following the evidence-gathering stage, students worked in their groups to generate claims as to which of the four walls most likely represented their climatic scenario. Using the claims–evidence–reasoning structure within Zydeco, groups took turns presenting their findings to their classmates. After all four scenario solutions were revealed, the teacher facilitated a deeper whole-class discussion related to human impacts on biodiversity.

Analytic Approach

For the purposes of this analysis, Chinn *et al*'s third dimension was broken into three constituent parts: "Sources of knowledge," "justification of knowledge" and "epistemic stance." "Sources of knowledge" was evaluated using the EvoRoom pre/post survey, in which students were asked to identify their main sources of knowledge in school science. Responses were open-ended, and the frequency of each response was recorded using a tally system, with students often reporting multiple sources of knowledge within a single answer. "Justification of knowledge" for both the Zoo Field Trip Activity and the Biodiversity Activity was examined using a qualitative, descriptive analysis of students' Zydeco contributions, with researcher field notes facilitating a comparison of the way knowledge was justified in each of these contexts. Additionally, a post-survey item asked students to identify the knowledge negotiation strategies that were used throughout the Biodiversity Activity.

An analysis of epistemic stance at the group level was conducted for the Biodiversity Activity only, since knowledge claims for the Zoo Activity were submitted individually. Students responded to a post-survey item asking whether their group reached a consensus on their final claim statement. Responses to this survey item were then cross-referenced with the "solutions" to the Biodiversity Activity, indicating whether or not their final claim statement was actually correct. In cases where there was consensus within the group and the claim statement was correct, responses were coded as "true certainty." In cases where there was consensus within the group but the claim statement was incorrect, responses were coded as "false certainty." Finally, in cases where a group consensus was not reached, responses were coded as "uncertain."

Analysis and Findings

Sources of Knowledge

The sources of knowledge students identified in this pre-survey (n=43) mainly consisted of authoritative sources (89%) such as the course textbook (34%), the teacher (32%) and other authoritative sources such as online resources or publications (23%). Only a small percentage of students identified themselves (3%) or their peers (8%) as sources of knowledge. Throughout the EvoRoom curriculum activities, students were asked to draw from a variety of knowledge sources in order to make contributions to the shared knowledge base, and also to regard the shared knowledge base as their community resource, representing the pooled ideas and knowledge artifacts contributed by their peers. In the EvoRoom Post-Survey, students were asked to identify the sources of knowledge they used throughout the EvoRoom curriculum unit. Here, there was a dramatic shift in the sources of knowledge that students identified. Results indicated that 33% of responses included authoritative sources (e.g. textbook, teacher, other external sources), 28% of responses identified their peers and/or the knowledge community as a source of knowledge (e.g. peer discussion, shared knowledge base, aggregate displays), and 38% of students identified themselves as sources of knowledge (e.g. through primary observations, prior learning/memory, reasoning/logic) (see Figure 2).

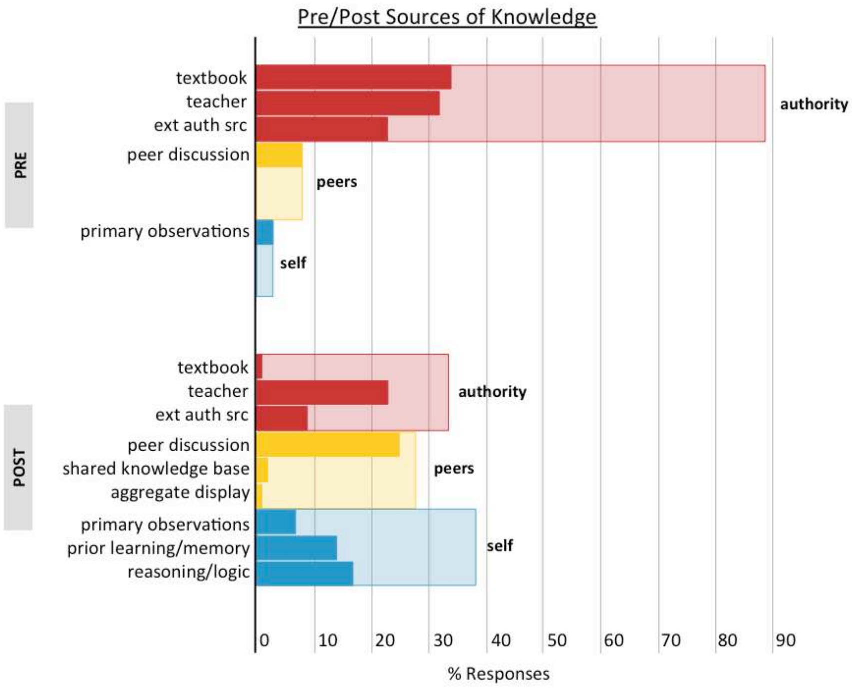

Figure 2. Pre and post survey results showing students' sources of knowledge in 'traditional' school science (pre) and in the EvoRoom curriculum (post). Pre-survey results indicate a heavy reliance on authoritative sources of knowledge (89%), whereas post-survey results show a more even distribution between authority (33%), peers (28%) and the self (38%) as sources of knowledge.

Justification of Knowledge

For both the Zoo Field Trip and the Biodiversity Activity, justification of knowledge was built into the design of the Zydeco app, as students had to provide both evidence and reasoning to support their claims statements. However, the way that this justification was enacted was quite different between these two contexts. For the Zoo Field Trip, although students collaborated to collect data, pool their evidence, and draw from this shared evidence base, students' final knowledge claims were ultimately completed individually. Questions were open-ended, and students had to be conscientious about their choice of evidence and reasoning in order to perform well on this summative assignment. The Biodiversity Activity, however, had three key differences: (1) students completed their knowledge claims in groups, (2) there was a "right" and "wrong" answer, and (3) this activity was not explicitly for marks. In contrast to the Zoo activity, field observations revealed that use of evidence artifacts to support claims statements in the Biodiversity Activity was almost an afterthought, with group consensus taking priority over evidential justification. Here, the majority of knowledge negotiations among group members occurred verbally, with Zydeco claim statements reflecting the product of these negotiations. The EvoRoom post-survey revealed that the negotiation strategies students described as occurring throughout this activity included taking turns "reasoning out loud" (41%), using the process of elimination (18%), collecting additional evidence (11%), using argumentation/debate (11%), listening in to other groups' decisions (9%), and bringing the decision to a group vote (9%).

An additional finding for the Biodiversity Activity was related to the quantity of evidence that students used in their claims statements compared to their ability to correctly identify their climatic scenario. As shown in Figure 3 below, Session C used the highest percentage of the data artifacts that they collected as supporting evidence in their claims statements (93%). At the same time, Session C was the only session for which all four groups correctly identified their climatic scenario. In Session A, which had the second highest percentage of evidence artifacts used towards claims statements (57%), one of the four groups correctly identified their climatic scenario. However in Sessions B and D, which used 38% and 29% of evidence artifacts, respectively, none of the groups were able to correctly identify their climatic scenario. These findings highlight the importance of evidentiary justification in supporting collective knowledge negotiations.

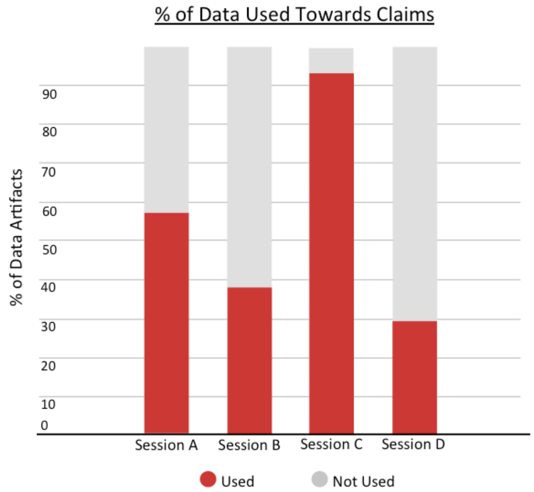

Figure 3. The percentage of data artifacts within each Biodiversity Activity session that were used as supporting evidence throughout the generation of group knowledge claims.

Epistemic Stance

Epistemic stance refers to the position one takes with respect to a knowledge claim (e.g. certainty, uncertainty, entertaining an idea, utilizing an idea as a working hypothesis, withholding judgment on an idea, etc.). For activities in which students collaboratively negotiate knowledge, such as in the generation of knowledge claims within the Biodiversity Activity, there are opportunities for students to take a variety of epistemic stances with regards to shared ideas or decisions. In each of these cases, it is possible that a student may be engaged in collaboratively generating a knowledge contribution, however he/she may have an epistemic stance that is in contrast or conflict with that of her collaborating peers. Satisficing one's true epistemic stance in order to appease group members (e.g. by establishing consensus within the group by means of a "vote") would detract from the justificatory rigor of the inquiry.

The Zydeco Biodiversity claims were analyzed in order to identify possible instances of satisficing within group responses. Following the Biodiversity Activity, students were given a survey in which they were asked to report whether or not their group reached a consensus about which rainforest depicted their scenario. 39% of respondents indicated that their group had consensus throughout the duration of the activity, 45% indicated that they came to a consensus after engaging in some knowledge negotiations, 11% indicated that they came to a consensus by "voting" or satisficing their response, and 5% did not reach a consensus. These responses were then cross-referenced with the group claims statements that were submitted through Zydeco. Responses were coded for group Epistemic Stance using the following categories:

1. **True certainty** – there was consensus in the group and the claim was correct
2. **False certainty** – there was consensus in the group but the claim was incorrect
3. **Uncertainty** – there was no consensus in the group

Results indicated that "False certainty" occurred in 58% of cases and "True certainty" occurred in 37% of cases. As noted above, only 5% of students reported that they did not reach consensus and their claim statements were therefore uncertain. Within the sub-set of students that reported satisficing their responses, only 25% of these groups were successful in correctly identifying their climatic scenario.

Discussion

Findings for "sources of knowledge" demonstrated that engaging students in activities where they rely on the ideas of their peers, as well as their own observations, can result in a noticeable shift in their epistemic cognitions within this dimension. However, the analysis for "justification of knowledge" revealed a distinct contrast between the way knowledge justifications occurred for individual knowledge claims (i.e. the Zoo Field Trip Activity) versus group knowledge claims (i.e. the Biodiversity Activity). Although the technological scaffolds within Zydeco were identical in both cases, these two activities were pedagogically quite distinct. The "claims statements" that students generated for the Zoo Field Trip Activity were in response to open-ended questions related to a driving question about the unity of biodiversity. Conversely, the claims statements within the Biodiversity activity were in response to a closed-ended, right-or-wrong question (asking which of the four walls of the EvoRoom depicted a particular climatic scenario). Here, group consensus was favored over justificatory rigor, and the addition of supporting evidence to claims statements commonly occurred after a group decision had already been reached. As a result, 58% of students were "falsely certain" that their claim was correct (i.e. their group had reached a consensus, however their claim statement was ultimately incorrect). This lack of evidentiary justification to support group claims statements is indicative of the satisficing of epistemic stances within the group. However, as indicated in Figure 2, groups who used more evidence to support their claims statement were more likely to reach "true certainty" (i.e. where their group had reached a consensus and their claim statement was correct).

In light of these findings, the following design priorities are recommended with respect to "justification" and "epistemic stance":

1. Although technological scaffolds to support evidentiary and non-evidentiary justification were built into the design of the shared knowledge base, the technology environment should also capture knowledge *negotiations* amongst members of the knowledge community. This would not only assist in preventing student satisficing, but would also to provide a history of the idea-growth *process* within the knowledge community.
2. To support the justification of knowledge in collaborative contexts, inquiry questions should be open-ended and should promote explanatory coherence over 'correctness.'
3. From a pedagogical perspective, activities should be designed that help students to understand the importance of justificatory rigor and how the satisficing of their epistemic stance in group learning activities might compromise the integrity of the inquiry.

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