

Scaffolding Scientific Epistemologies through Knowledge-Building Discourse and Epistemic Reflection

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Abstract: This study investigated how elementary-school children's science epistemologies can be fostered in a CSCL knowledge-building environment focusing on epistemic inquiry and reflection. Two classes of fifth graders in Hong Kong participated in a unit of electricity study. The design involves students engaging in scientific inquiry, pursuing ideas on Knowledge Forum®, and making epistemic reflection about the inquiry process. A key design theme involves children reflecting on their inquiry in relation to scientific practice and collective theory building. Analyses indicate that online discourse moves reflecting epistemic inquiry (problem-centred uptake and theory building) were correlated with post-test epistemic and conceptual understanding. Classroom and interview analyses showed how students' epistemic practice (e.g., theory revision) and epistemic reflection (connecting their own inquiry and scientists' inquiry) might have influenced their epistemic development. Implications of how children develop scientific epistemologies supported by epistemic inquiry, discourse and reflection in a knowledge-building environment are discussed.

Keywords: knowledge building, CSCL discourse, epistemic views of science, scientific inquiry

Helping students understand the nature of science and scientific inquiry has always been the central focus of science education. A growing number of studies have been conducted to understand students' epistemic views of science, and its relation to other cognitions (Stathopoulou & Vosniadou, 2007; Tsai & Liu, 2005). However, few studies have examined how it can be fostered, especially how it can be fostered in computer-supported collaborative learning (CSCL) environments. The purpose of this study is to examine how a computer-supported knowledge-building environment may facilitate students' scientific epistemologies and knowledge advances.

Theoretical perspective

Epistemic views of science and CSCL

Epistemic cognition is individual's understanding about the nature of knowledge and knowing (Chinn, Buckland, & Samarapungavan, 2011). There are different lines of research conceptualizing epistemic cognition (Hofer & Pintrich, 1997; Lederman et al., 2002; Schommer, 1990), among which one line focused on the idea-driven and constructive nature of science. Carey et al. (1989) initiated this line of research and identified three general levels of epistemic understanding among seventh grade students, ranging from viewing science as concrete activity to viewing it as an idea driven process and as construction of ever-deeper explanations of the natural world. Later Smith et al. (2000) made a more elaborate study of sixth graders' epistemologies of science, and differentiated different aspects of the epistemology (e.g., goals of science, the nature of scientific questions, etc.). Chuy, Scardamalia and colleagues (2010) further developed the interview protocol, emphasizing on theoretical progress. The epistemic cognition framework this study used was based on these previous studies and examined how students understand science as an idea driven process, and it further extends it to the social aspect, and focuses on how students understand the collective and progressive nature of scientific progress.

Many studies have designed computer supported collaborative learning (CSCL) environments to support students' scientific inquiry with some indicating that the epistemological design of those environments could influence the nature of students' inquiry process (Clark, Weinberger, Jucks, Spitulnik, & Wallace, 2003). For example, Tan et al. (2005) noted the change of students' epistemology and scientific inquiry skills in a computer supported collaborative learning environment. Underlying these designs and technologies is the emphasis on role of epistemology and that scientific knowledge is socially constructed and advances in a progressive manner. However, how students understand science's progressive and socially constructed process and how it relates to their scientific inquiry practice is not well examined. We argue here that it is important to examine how individuals understand science as a collective theory building process and how they understand its social and progressive nature, as this may help to explain students' collaborative knowledge construction

process in CSCL environments. It could also help us to reflect on and improve the epistemic principles of the technology used to support students' collaborative inquiry.

Computer supported knowledge building

As one of computer-supported inquiry-based models in education, knowledge building has attracted much of the attention in the recent years (Scardamalia & Bereiter, 2006). One essential aspect of knowledge building is students taking collective cognitive responsibility for community knowledge advancement. In knowledge building, ideas are viewed as conceptual artifacts that can be constantly improved. To support such knowledge work, Knowledge Forum® (KF) has been created as a communal place where ideas can be worked on in various ways (e.g., linked to other ideas, be visualized with structures, be highlighted with graphs, and be revised, etc.). Scaffolds are also provided for students to work towards knowledge building: "*I need to understand*", "*my theory*", "*new information*", "*a better theory*", "*putting our knowledge together*", etc. These epistemic prompt may help develop students' epistemic understanding about the collective theory building nature of science.

A growing number of studies have been conducted to examine the design and effects of knowledge building on students' science learning (Hakkarainen, 2004; Lee, Chan, & van Aalst, 2006; Oshima & Scardamalia, 1996). Results have shown the role of knowledge building discourse and classroom dynamics on students' understanding (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). However, few studies have explicitly relate knowledge building with students' scientific epistemologies drawing upon online and offline data (Chan & Lam, 2010; Chuy et al., 2010). Therefore, the purpose of the current study was to address this issue, and to examine how knowledge building may foster students' epistemic and conceptual growth. This paper is based on a large project that examines the design, processes and effects of a knowledge-building environment on students' epistemic and conceptual understanding. In a preliminary study (Lin & Chan, 2014), we have reported on the quantitative findings indicating that knowledge-building students improved more on their epistemic and conceptual understanding than the comparison group. This study draws upon the data from Knowledge Forum, classroom observation, and interviews to examine how the design might have fostered students' epistemic growth and knowledge advances. Specifically, three research questions are addressed: (1) How do Knowledge Forum inquiry and discourse relate to students' epistemic and conceptual understanding; (2) How does classroom dynamics including discourse and reflection facilitate students' epistemic growth; (3) How do students understand their own and scientist inquiry reflected in their interviews? -

Methods

Participants and context

As noted above, this is part of a large design study. Four classes of fifth graders in Hong Kong participated in the study, among which two classes (n=52) were engaged in knowledge building and epistemic reflection, for comparison, the other two (n=50) were taught with regular inquiry-based approach. This paper focuses on the knowledge-building classes.

Designing the knowledge-building environment: Students as little scientists

The key design is to help students work like little scientists engaging in epistemic inquiry and reflecting on the inquiry process collectively. Students pursued ideas (e.g., pose questions/explanation; revise idea) on Knowledge Forum (KF), tested their ideas in experiments; and reflected on their inquiry process integrating online and offline discourse. The specific designs include: (1) *Activate prior epistemic and conceptual understanding*: Students discussed their initial ideas about electricity and what scientists do in the classroom (2) *Authentic problems and inquiry*: Students watched a video on experiments about lemon juice/ salt water conducting electricity, conducted hands-on experiments to test conductivity of different materials; posed wonderment questions and put their ideas and questions on KF; scaffolds were provided (e.g., "*I need to understand*", "*my theory*", "*new information*") to facilitate theory building. (3) *Deepen inquiry through experiments and classroom epistemic talk*: Students worked in groups to design experiments to test their KF ideas; they reflected on their forum discourse and inquiry and wrote on KF their epistemic understanding; (4) *Connect students' inquiry with scientists' inquiry through epistemic reflection*. Students were scaffold to reflect on the relations between their own inquiry and scientists' inquiry (5) *Knowledge building reflection*: Students wrote portfolio notes on KF to reflect on their collective discourse with knowledge building principles.

Analyses and results

The previous paper has reported on preliminary analyses; students' epistemic views of science were measured with a written test developed from previous studies (Carey et al., 1989; Lederman & Ko, 2004; Smith et al.,

2000). Four components were identified to characterize epistemic views: (1) role of idea, (2) theory building (3) theory-fact understanding, and (4) social process of scientific progress. The general pattern ranges from viewing science as concrete activities to seeing it as collective theory building process. Quantitative analysis indicated that the knowledge-building group improved more in their epistemic and conceptual understanding than the comparison group (Lin & Chan, 2014). While quantitative findings show positive effects, questions remain as to how the designed environment facilitated students' epistemic and conceptual growth. This study specifically examined how Knowledge Forum inquiry (online) and classroom inquiry and dynamics (offline) might contribute to the change. Students' focus group interviews were also examined to explain the change processes.

Q1: Examining Knowledge Forum discourse and relations with epistemic and conceptual understanding

Among the two knowledge-building classes, Class 1 students on average wrote 13.2 notes, linked 66.7% of the notes, and read 30.4% of the total notes. Class 2 students on average wrote 7.5 notes, linked 52.7% and read 32% of the notes; these indices are comparable to those in knowledge building research (Lee et al., 2006). To characterize the socio-cognitive-epistemic aspects of knowledge building discourse, analysis of Knowledge Forum notes was conducted both on thread and individual note levels. The notes were first parsed into threads, and coded into three patterns: knowledge sharing (sharing of information), knowledge construction (interacting to construct understanding), and knowledge building (working to extend and create knowledge) (van Aalst, 2009). The following excerpt shows an example of a knowledge building thread.

Student#	Note content
5a03	I don't understand]: Why can salt conduct electricity?
5a34	Because salt is a kind of electrolyte
5a16	[A better theory]: after the experiment, we found that both salt and salt water can not conduct electricity
5a20	[You theory can not explain]: After this experiment, we found that salt can not conduct electricity, but salt water can. Salt water is NaCl, it is ionic compound, and there are free electrons or ions in it. Therefore it can conduct electricity.
5a34	[A better theory]: because salt consists of Na ⁺ and C ⁻ , Na ⁺ is metal ion, can allow free electron pass through. Na ⁺ and K ⁺ transmit as nerves in our brain, therefore salt can conduct electricity.
5a31	[I don't understand]: can anything that does not contain Na ⁺ conduct electricity?
5a11	[Your theory cannot explain]: Salt is a kind of metal ion, and can conduct electricity; salt water is a kind of soluble liquid with salt. Any liquid that can dissolve salt can conduct electricity, because there are free electrons in it, and it is called electrolyte. [My theory]: any liquor with electrolyte can conduct electricity.

As the excerpt shows, student 5a03 started with an alternative conception (misconception), asking why salt conduct electricity. 5a34 proposed a theory that salt is a kind of electrolyte. Then 5a16 used the evidence from the experiment to question her classmates' conception noting salt cannot conduct electricity, but he also included a misconception noting salt water cannot conduct electricity. 5a20 noted the problem and explained why salt water can conduct electricity (*"Salt water is NaCl, it is ionic compound... there are free electrons or ions.. it can conduct electricity"*). However, 5a34 then proposed a theory to explain why salt conduct electricity. The idea of Na⁺ from 5a20 and 5a34 brought about an emergent question from 5a31 wondering if anything without Na⁺ can conduct electricity. That led to 5a11 proposing another theory explaining why salt water conduct electricity, he used the example of salt water conducting electricity to generate the principle that *"Any liquid that can dissolve salt can conduct electricity, because there are free electrons in it, and it is called electrolyte."* Further, he came up with a new theory that *"any liquor with electrolyte can conduct electricity."* This example showed how this group of young students worked collectively at something well beyond their curriculum: they devoted theory-building and knowledge-creation efforts to pose questions and explanations and to continually revise earlier ideas; they provided explanations about why salt water conduct electricity and gradually developed a more abstract theory; new information was embedded along the discussion; misconceptions existed but continually revised. This example showed how study collectively built ideas on Knowledge Forum to advance their community knowledge.

Notes within the conceptual threads were also analyzed quantitatively for understanding discourse moves. Premised on knowledge building theory, two components were identified: *Problem-centred uptake* and *Theory-Building*. (1) *Problem-centred uptake* discourse moves refer to how coherently the idea was connected to previous idea to address the original problem and also for deepening the inquiry. Four levels were coded: At level 1, the note makes no/weak connections to the previous note. At level 2, there is vague connection; the response is not essential for solving the problem (e.g., ask for elaboration). At level 3, the note has reasonable connections to the previous note (e.g., give explanations to the previous questions). At level 4, there is coherent connection in terms of solving the problem (e.g., move discussion back to the problem; rise above; ask deepening question). (2) *Theory building* includes discourse moves that illustrate efforts to build theory, including initiating inquiry, sustaining inquiry, theorizing (explanation), responding, and using social-cognitive conflict to spark progress (see Table 1).

Table 1: Coding scheme for theory building effort

Code	Description
Initiate inquiry	Initiates a thread; starts with a question or a statement
Theorizing (low)	Provides simple explanation; intuitively try to provide reasons for a phenomenon.
Theorizing (high)	Constructs deep explanation; search for abstract mechanism-process, or the complex observable mechanism of a phenomenon, incorporated with new information/evidence
Sustain inquiry (low)	Asks simple or superficial questions for elaboration or explanation.
Sustain inquiry (high)	Asks deepening question that sustain inquiry for progressive problem solving e.g., ask for explaining the mechanism; emergent questions
Response (low)	Responds to the previous notes with simple factual word or statement (differentiated from explanation that tries to theorize for mechanism).
Response (high)	Reasonable and elaborated responses to the previous notes, embedded with new information (differentiated from explanation that tries to theorize for mechanism).
Social cognitive conflict	Identifies problems/misconceptions; questions ideas under discussion to move forward
Non-build on	Scattered notes without any build on; or other irrelevant note

Correlation analysis was conducted to examine the relations of discourse moves with students' epistemic and conceptual understanding (Table 2). Forum participation was examined using a tool called Analytic Toolkit and different indices (e.g., read, write, scaffolds) were combined using factor analyses (Lee et al., 2006). Analyses showed that students post-test conceptual understanding was correlated with post-test epistemic cognition, KF participation, KF high problem centred uptake (level 3+level4), and KF explanation and response (high). As well, students' post-test epistemic cognition was correlated with KF high problem centred uptake, KF explanation and response (high), and KF sustain inquiry. These results suggest that students' problem-centred uptake and theory building moves are related to their epistemic and conceptual understanding.

Table 2 Correlation among KF discourse, post conceptual understanding, and post epistemic views (n=52)

	1	2	3	4	5	6	7	8
1.Post-test conceptual								
2.Post-test epistemic	.489**							
3.KF participation (ATK)	.320*	0.247						
4.KF high problem-centred uptake	.378**	.339*	.698**					
5.KF initiate inquiry	0.126	0.08	0.275	0.24				
6.KF explanation & response (high)	.412**	.292*	.728**	.822**	0.185			
7.KF sustain inquiry	0.168	.289*	.492**	.812**	0.228	.463**		
8.KF socio-cognitive conflict	0.218	0.175	.315*	.415**	0.114	0.19	.482**	
9.KF nonbuild on	-0.241	-0.091	.276*	-0.035	0.201	-0.043	0.174	-0.043

Note: *p<.05; **p<.01

Q2: Scaffolding Epistemic Discourse and Reflection in the Classroom

This study also analyzed key themes emerging in the knowledge building classroom reflecting students' epistemic inquiry and practice; online and offline discourse were integrated. There are many key events and the selection was guided by framework emphasizing epistemic reflection and theory building.

Epistemic inquiry activating prior knowledge and asking questions

In the knowledge-building classroom, from the start, the focus is about letting students develop practice of raising questions and constructing explanations and improving on these ideas. Students asked various questions

about electricity (e.g., *why does water conduct electricity? What makes conductor conduct electricity?*). Question generation is key to scientific inquiry/progress; students posed problems on KF and in class to acculturate students into epistemic practice of problem-centred inquiry. The teacher also scaffolded students to consider their views of science, and to link their experiments with scientific practice and theory building.

Theory revision in scientific and epistemic inquiry

The teacher scaffolded students to understand role of idea and theory revision from their own inquiry experience. To test the various ideas on Knowledge Forum, students worked in different groups to design experiments (each group worked on their question, theory, hypothesis and design in a piece of poster). One group observed that water does not conduct electricity, and they proposed a theory (explanation) "*it is related to the materials of the cup; the cup that holds water is plastic, which is insulator, and so the water in the cup cannot conduct electricity*". The teacher worked with this group to test their 'cup theory'. They came up with the idea of testing the conductivity of water held by different cups (plastic, wooden, and metal). The experiment was conducted and the teacher initiated an epistemic discussion with the whole class after that.

SW: we found that even we put the water in different cups, the brightness of light is similar.

T(Teacher): **how are these findings different from the group's hypotheses?**

SW: It means that the hypotheses about the plastic cup & wooden cup were wrong (they hypothesized that the water held by plastic and wood cup cannot conduct electricity).

T: why are the hypotheses wrong**Do you still remember the theory?....**

SC: we observed that the water in the wood cup can make the light a little bit brighter; it may be related to the impurity in the wood.

SG: the light showed similar brightness with whatever cups, it means that...

Ss: it has nothing to do with the cups...

T: **I appreciate SC mentioned something new**, he mentioned ... [The discussion continued...]

T: ..now suppose you are the scientists, **how would you revise your theory**[Ss wrote on papers]

SY: it is related to the amount of the water

SM: it is related to the different kinds of water, such as running water, distilled water...

This example illustrates how different ideas develop in classroom/KF discussion with students coming up with their ideas (cup theory) tested in experiments, and how students began to see that their theory (idea) need to be tested and revised similar to scientific practice. Another interesting theme is that while the teacher expected students to discuss based on the central problem (materials of cups), one student SC mentioned some unexpected results and proposed a new theory to explain the phenomenon (*the light of the wood cup is a little bit brighter, maybe related to impurity in the wood*), which pointed to experimental error and possibly a new direction for further inquiry. The process was similar to the emerging process of the mature scientific inquiry, which involves theory testing and theory revision. This experience might have influenced how students understand science as a theory revision and theory building process.

Epistemic inquiry into their and scientists' knowledge-construction processes.

In this knowledge building classroom, to scaffold students to engage in scientific and epistemic inquiry, students were involved in designing, testing ideas, and reflecting on their inquiry. Students wrote on the poster (Figure 1) their experimental design (prompts: problem, theory, hypothesis, design). In the same poster, they also wrote their views of science (prompts: what is science? Are we investigating like scientists? And how do scientists construct knowledge?). The following excerpt showed an example of the epistemic discussion:

Student A: how do scientists construct knowledge?

Student B: with their mind

Student Y: by doing experiment

Student W: is that doing experiment can bring us knowledge? I did so many experiments, why didn't I not construct knowledge?

Student Y: because you just do experiment.

Student W: but you said scientists do experiment to construct knowledge....

- Student B: by discussion....discuss problems..
- Student A: are we working like scientists?
- Student Y: do experiment, and constantly doing inquiry.
- Student B: we will investigate problems we don't understand.

This example illustrates how epistemic talk, or having students explicitly discuss how science knowledge is created, might help them understand more about their own inquiry and nature of science. These children started with a naïve or impoverished idea (scientists construct knowledge with their mind), and gradually came to understand more about the role of discourse and experiment for constructing knowledge. Though the discourse is still preliminary, children might begin to see more about the constructive nature of science and need for sustained inquiry to tackle problems they didn't understand.

Using an epistemic model to reflect on collective theory building

One of the culminating activities involves using an epistemic model to scaffold epistemic reflection: The teacher showed students a visual representation (Little Scientists Worksheet) that illustrated a simplified model of the structure of scientists' collective inquiry. As Figure 2 shows, Scientist A asks a question, proposes theory A to address the research problem; Scientist B questions scientist A's theory and proposes theory B; Scientist C further improves scientist A's theory and proposes theory C; Scientist D synthesizes scientist B and scientist C's theory into theory D. Different arrows are connected to indicate inquiry is an ongoing process. Students were asked to *indicate* elements that were similar to what they have experienced. The teacher initiated an epistemic discussion among students, as the following example shows.

- T: You have played different parts... in your inquiry. Many of you asked questions and proposed theories, um...like scientist A... ...so [what about] scientist B? Is there no need for Scientist B?
- Ss: no, we need scientist B and C to question [them], so that we can improve the theory....
- T: ...None of you mentioned scientist D...?
- SW: ...[we need] scientist D... could combine scientist B and C's theories, and make a better theory

This example suggests how the prototypes of different scientists, in the form of an epistemic model, might help students to see the similarity between what they do and what scientist do illustrated in the model, and therefore might prompt students to develop a better epistemic understanding about scientists' inquiry process.

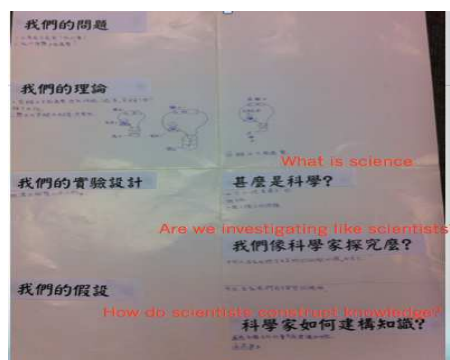


Figure 1. Group poster

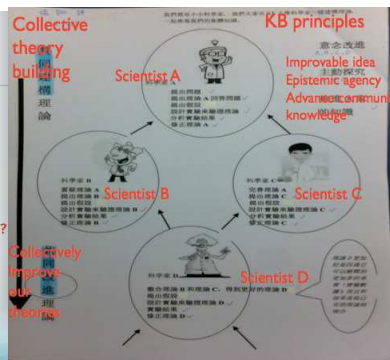


Figure 2. Little Scientists worksheet

Q3: Examining students epistemic understanding via interviews

From viewing science as inventing concrete things to viewing it as theory building process

Consistent with the quantitative findings about the impact of the designed environment on students' epistemic change, qualitative analysis of students' focus group interview also showed that many students initially thought of scientists as only doing experiments or inventing things, but that, after the program, they started to understand the role of idea and social cognitive conflict in science. For example, student CFM said:

I used to think that scientists only researched something to help people, but after this semester (after knowledge building), now I understand that scientists not only research something, they will ask questions, which people don't know yet... then other scientists will continue to ask

him why is that... I thought scientists only invented things, and never thought they proposed theories.

For the students who already had some understanding of the role of idea in science, they mentioned that they had further realized how scientists work together to improve knowledge, and spontaneously connected it to what they did in Knowledge Forum, as one student reflected:

“Before, I thought scientists just investigated something, and then made a theory. Now I understand how scientists push each other forward...(Can you explain what you mean by ‘push each other forward’).. **Just like how we ask questions in Knowledge Forum**, then we answer each other’s questions. Scientists also have their own questions, then other scientists or they themselves may find the answers, then there will be more questions...and answers. So that they can organize their theory...and it kept circulate.”

From seeing themselves as knowledge receivers, to seeing themselves as knowledge creators

To build and create knowledge, one must not only understand the knowledge-creation process, but must also believe in their capability to create knowledge. Interviews showed that students started to see themselves as knowledge creators, rather than mere knowledge receivers, after their experience with knowledge building, as one student FYL reflected, “I used to think that knowledge only existed in the textbook, actually, we have lots of problems around us that have not been explored yet.” Another student HBY said, “I also thought knowledge only existed in books. [Now I understand that] many people can create knowledge. And we ourselves can also create knowledge...” In addition to believing in their capacity to create knowledge, they also started to see knowledge creation as a socially constructed process. For example, student CHEN said

...Now I think that knowledge can not only be obtained from the book, but also generated by our discussion....it is not only limited to the Internet, books... I now think we ourselves can also discover knowledge...(Can you explain more about ‘discover knowledge’)...discuss with classmates. In Knowledge Forum, when someone asked questions, we would try to answer the question, while we were thinking and solving the problem, we learned new things....you will rely on some of the material on internet, and incorporate them into your own thinking, and generate new knowledge.

This excerpt showed that CHEN used to think knowledge could only be obtained from books, but came to see himself as able to generate knowledge. He also started to think that knowledge was generated by questions, and was socially constructed. He even mentioned how students could make constructive use of authoritative information from the Internet to help them construct knowledge.

Discussion and conclusions

The study investigated how epistemic and conceptual growth could take place in the designed knowledge-building environment. Discourse and correlation analysis indicated that students’ high level problem centred uptake and theory building moves were related to post-test epistemic and conceptual scores. Analysis of classroom dynamics showed both students’ inquiry in the classroom (problem-generation, theory revision, design experiment to test KF ideas) and how epistemic reflections scaffolded by epistemic inquiry, discourse, and modeling have facilitated students’ change of epistemic and conceptual understanding. The study showed that it is not adequate just to have students engage in inquiry tasks and forum writing; they need to reflect on their inquiry and we scaffold them to reflect on their own inquiry in light of scientists work. Interviews further showed the impact of the designed environment on students’ epistemic understanding, and how students have changed from viewing science as concrete activities to theory building process, and how they started to see themselves as knowledge creator and to appreciate the role of collective theory building in knowledge creation.

This epistemic-enriched knowledge-building design is very different from the traditional inquiry-based approach, in which science is portrayed as a series of observation and experimentation, and which neglects the role of ideas in inquiry. The traditional simple inquiry, as Chinn and Malhotra (2002) put it, assumes an epistemology *opposed* to the epistemology of authentic science. Students’ interpretation of these “artificial” inquiry tasks may affect how they understand the nature of knowledge and science. For example, if students merely do experiments without knowing that the purpose of experimentation is to test ideas, they may not understand the role of ideas in science; similarly, if students merely make posts on computer forums, or argue claims without attempt to improve them, they may not understand that ideas and theories are socially constructed that can be improved through online discourse. Accordingly, one possible explanation for the changes in epistemic understanding among students might be that underneath knowledge building is an

epistemology that is similar to that of the authentic scientific inquiry, and students' inquiry and reflection is a process of internalizing experts' epistemology, and therefore a process of improving their own epistemology.

This study has shown the possibility of changing students' understanding of the nature of science through a computer-supported knowledge building design. Our findings are consistent with the postulation that, if students are to understand certain aspects of the nature of science, they must experience those aspects and make metacognitive reflections thereon (Carey et al., 1989). This study also suggested that the kind of epistemic discourse that facilitates connections between scientific inquiry and their own knowledge building inquiry might be helpful for epistemic growth. Knowledge building theory (Scardamalia & Bereiter, 2006) postulates that members add value to knowledge production, similar to scientific communities. This design might make this more explicit with students working as little scientists; engaging in theory building; and reflecting on such processes as scientists and knowledge builders. The study has also identified the need to investigate further how to embed epistemic features, such as the *collective*, *ever-deepening*, and *progressive* nature of knowledge, into CSCL pedagogy to improve epistemic cognition. Future study can be conducted to further explore the role of epistemic discourse and reflection in students' epistemic change process.

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