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Improving 10-12 Year Olds' Epistemic and Conceptual Understanding in a Computer-supported Knowledge-building Environment

Feng LIN [a*], Carol K.K. CHAN[a]
[a]*Faculty of Education, The University of Hong Kong, Hong Kong*
*irisfeng83@gmail.com

Abstract: This study investigated the design of a computer supported knowledge-building environment in fostering 10-12 year olds' epistemic and conceptual understanding. Two classes of 5th graders in Guangzhou China participated in this study while they were learning a unit about electricity. One class engaged in knowledge building, supported with a computer supported platform--Knowledge Forum®, and the other class was taught with traditional approach for comparison. The results showed significantly stronger effects on epistemic view of science and conceptual understanding for knowledge-building group compared with the traditional group. Regression analysis showed that knowledge-building environment and post epistemology of science contributed to students' post scientific understanding, over and above their prior science knowledge. Qualitative analysis of students' Knowledge Forum discourse and interviews showed how the design had helped improve students' epistemic view on the social and progressive nature of scientific inquiry and conceptual understanding.

Keywords: Knowledge building, epistemic view of science, conceptual understanding, CSCL

1. Introduction

The research on the design of computer-supported collaborative learning (CSCL) environment has received much attention in the recent years. Studies have been conducted to investigate the effectiveness of CSCL on students' conceptual change, inquiry process, and other cognition and skills (Liu & Hmelo-Silver, 2007; Tao & Gunstone, 1999; Vosniadou & Kollias, 2003; Hakkarainen, 2003; Lazakidou & Retalis, 2010; Salovaara, 2005). However, very few have been conducted to examine its effect on students' epistemic view of science (Chan & Lam, 2010). Sophisticated epistemic view of science is important as part of students' scientific literacy. Researchers have proposed different ways to conceptualize epistemic view of science. This study built on the line of research that examined students' epistemic view of science from the role of idea and theory building perspective (Carey, Evans, Honda, Jay, & Unger, 1989; Carey & Smith, 1993; Chuy et al., 2010; Smith, Maclin, Houghton, & Hennessey, 2000), and extended it to examine students' understanding about the social aspect of the theory building process in science. Previous research has shown that many students have naïve epistemic view, and they regard science as concrete activities rather than idea-driven process (Carey et al., 1989; Smith et al., 2000). Therefore, the current study is trying to design a computer-supported knowledge-building environment to improve students' epistemic view of science, and to help them understand the role of idea in science, and the collective and progressive nature of scientific inquiry.

2. Theoretical Background

2.1 Epistemic View of Science

Improving students' understanding about the nature of science has always be the focus of science education. Some science educators have proposed to examine students' nature of science views from seven aspects: tentative nature of science, empirically based nature of scientific knowledge, subjective nature of science, science involving human inference, imagination, and creativity, the relation and distinction between scientific laws and theories, and observation and inferences (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). It has been argued that even these seven aspects did not capture the whole nature of science, they were accessible to students and were well recognized by scientists and science educators(Lederman et al., 2002). Some other researchers have followed the psychometric tradition initiated by Perry (1970), Schommer (1990), and Hofer and Printrich (1997), and examined students' epistemological beliefs on science on four dimensions: development of knowledge, certainty of knowledge, justification for knowing, and source of knowledge (Conley, Pintrich, Vekiri, & Harrison, 2004).

Even though these approaches have portrayed the important aspects of the nature of science, the constructive nature of science was still neglected. Premised on constructivism paradigm, Carey et al. (1989) initiated a line of research that examined how students understand science as an idea driven process. Smith et al. (2000) and Chuy et al. (2010) further contributed to the line of research by elaborating on the specific components of the nature of science and making theory building more explicit. This study followed this line of research and examined students' understanding about the nature of science from the role of idea perspective. Meanwhile, we also tried to extend beyond it by focusing on the social aspect, to examine how students understand science as a collective theory building process, which involves negotiation of ideas, co-construction of ideas, and integration and creation of ideas.

2.2 Computer Supported Knowledge Building

Knowledge building is one of the inquiry based educational models focusing on knowledge creation and theory building. The central idea of knowledge building is about students taking epistemic agency and taking collective cognitive responsibility to advance the community knowledge (Scardamalia, 2002). To support students' knowledge building effort, Knowledge Forum®, a computer supported learning platform, has been created. It provides students with a multimedia community knowledge space where their ideas can be displayed, linked, built on, revised, and integrated (Scardamalia, 2004).

The design of knowledge building environment and its relation to students' learning outcomes has been examined by a growing number of studies (Chan, 2009; Lee, Chan, & van Aalst, 2006; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007; Zhang, Scardamalia, Reeve, & Messina, 2009). Scardamalia and Bereiter (2006) have been advocating that the goal of knowledge building is not to evolve into a series of procedures, but a pedagogy guided with workable principles. 12 principles have been proposed to guide knowledge building practice (Scardamalia, 2002), including real ideas, authentic problems, improvable ideas, idea diversity, rise above, epistemic agency, community knowledge, collective responsibility, democratizing knowledge, constructive uses of authoritative sources, etc.

To sum up, the purpose of this study is to examine the design of knowledge building environment on students' epistemic and conceptual growth. Three research questions were addressed: (1) Do students engaging in knowledge building achieve more epistemic and conceptual growth than students in traditional classroom? (2) What are the relationships among knowledge building, epistemic view of science, conception of collaborative discourse, and conceptual understanding? (3) How does knowledge building help students improve their epistemic view of science and conceptual understanding?

3. Method

3.1 Participants and Context

Two classes of 10-12-year-old 5th graders (n=61) in Guangzhou China participated in this study. One was engaged in computer-supported knowledge building inquiry, supported with Knowledge Forum; another one was taught with traditional approach for comparison. Students were learning a unit about electricity while we conducted the intervention. Both classes were taught by the same science teacher, who was experienced in science teaching and just started to learn knowledge building pedagogy. The whole intervention lasted for 3 weeks and was implemented in 6 sessions.

3.2 Designing Computer Supported Knowledge-building Environment

The knowledge building class was designed with knowledge building pedagogy and was mainly guided with four knowledge-building principles, “improvable idea”, “epistemic agency”, “constructive use of authoritative information”, and “community knowledge”(Scardamalia, 2002). The key idea of the design was about letting students pursue inquiry like scientists community. They posted their questions and ideas on Knowledge Forum, tested their ideas with experiment, and continued to revise and improve their ideas on Knowledge Forum. The specific design was described bellow:

(1) Initiate inquiry on Knowledge Forum. The first two classes were conducted in the computer room. After trying out the Knowledge Forum function in a demo view, students were asked to put their questions and ideas on the electricity view. We did not teach them how to respond to each other, but let them try out and figure out themselves. However, they were encouraged to use the scaffolds in their notes writing: “I need to understand”, “my theory (explanation)”, “new information”, “a better theory (explanation)”, “your theory cannot explain”. This session was mainly designed to put students’ ideas in the public place as subject to build on, and to let them get familiar with the Knowledge Forum functions.

(2) Reflect on Knowledge Forum discourse. After letting students experience the discussion on Knowledge Forum themselves, we designed a session on “what is good discussion”, so that they could reflect on the quality of their own discussion. We prepared two threads of notes, one was from their own Knowledge Forum discussion, and another one was from a primary science database in Hong Kong, which was chosen as a good model. We let students compare these two threads of notes and choose a better one. Then we let them discuss in groups and write down on poster why they think the chosen one was a better discussion. To nurture a knowledge-building culture in the classroom, students were asked to put their group poster on blackboard, and then everyone could write a note to comment and put the notes on the posters. This was designed to simulate the threads on Knowledge Forum and to let students aware that their ideas could be made in public and improved by the community. At the end of the session, the teacher related students’ collective ideas on the criteria of good discussion to knowledge building principles, and encouraged them to use these principles to guide their later Knowledge Forum discussion.

(3) Deepen inquiry. To make students have a more focused discussion, a deepening view was created, as Figure 1 shows. Many students were interested in the discussion on whether wet wood conducts electricity. They proposed different ideas and theories to explain the conductivity of wet wood. Then they were asked to work in groups to design experiment to test their own ideas. After students completed their designs, each group presented their design poster in the classroom, and put it on the blackboard for further improvement. Again students were asked to write notes to comment on the designs and stuck it on the poster, as Figure 2 shows. To make the classroom knowledge-building look as similar as the Knowledge Forum one, and also to make them aware of the connection between their classroom ideas and Knowledge Forum ideas, we put their Knowledge Forum question in the middle of the blackboard, and drew lines between students’ experiment designs and this question (Figure 2). It was hoped that this design could help students understand the role of idea in experiment. After the experiment, students were encouraged to continue to write on Knowledge Forum.

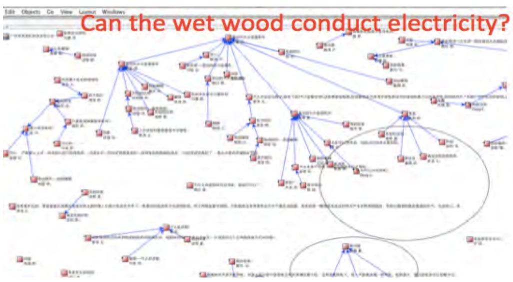

Figure 1 Deepening view on electricity

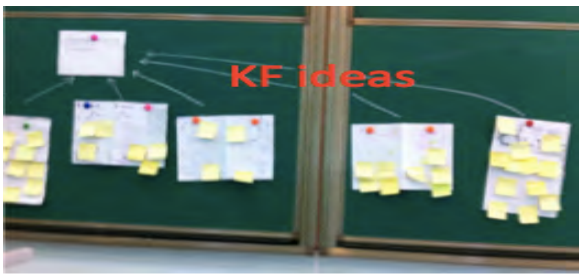

Figure 2 Visualize KF ideas in classroom

(4) Reflect on science learning and nature of science. At the end of the program, students were asked to reflect on their changed epistemic and conceptual understanding. They were asked to write in a piece of paper on “what I knew about electricity before, what are the new understanding I have now about electricity; what I knew about the nature of science before, what are the new understanding I have now about nature of science”.

The comparison class was also learning electricity but was taught with traditional approach. According to the teacher interview, in each class, he usually lectured first according to the textbook, and then would let students discuss among themselves. No scaffold was provided.

3.3 Measures

Written Test on Epistemic View of Science. Pre and post written test on epistemic view of science were given to all students to fill out before and after the program. The written test consisted of 7 items adapted from Carey, et al. (1989), Smith et al. (2000), Chuy et al. (2010), Conley et al. (2004), and Lederman & Ko’s (2004) items. Students were given 20-30 minutes to finish the test. Four components were identified to characterize students’ epistemic view of science: (1) Role of idea (“What is science”; “What do scientists do”; “How do scientists do their work”; “Why do you think scientists do experiment”); (2) Theory building (“How do you think new theory is developed”); (3) Theory-fact understanding (“What are the relationships between theory and fact”); (4) Social process of scientific progress (“Scientists may have different even contradictory ideas, do you think it is good for science?).

Premised on knowledge building theory, students’ responses were coded on a 3-point scale, ranging from viewing science as concrete activities to collective theory building process. Take an item on role of idea for example, at level 1, students do not understand the role of idea in science, they only mention some concrete activities scientist do, such as work in the lab, mix things together, and invent things (*“scientists do experiment in the lab”;“they pour tubes in the lab”)*; at level 2, students mention some abstract entity, such as theory, question, explanation, hypothesis, and laws, etc, and they also have some understanding about the connection between idea and experiment(*“They propose some ideas, and do experiment to prove”);* at level 3, students can make the connection between the abstract ideas and experiment, and also mention about the social aspects of science and knowledge creation(*“Scientists do experiment, questioning, propose new ideas, test ideas, and get conclusions”).* For the component on social process of scientific progress, at level 1, students do not appreciate the role of different ideas for scientific progress, or have some superficial understanding of the role of different ideas in science (*“It is a good thing, because it will improve scientists’ hard working spirit”);* at level 2, students appreciate of the role of idea interaction for science,(*“It is a good thing, because new evidence may come out from the argument”)*; at level 3, students understand the role of different ideas for theory improvement/knowledge creation (*“it is a good thing, if everyone has the same idea, there won’t be better ideas. When we combine different ideas, there will be a even better idea”).*

Interviews. Interviews were conducted before and after the program to examine students’ epistemic change process. Eight students from each class were recruited for the interview. The first part of the interview asked similar questions as the written test to have deeper understanding about students’ epistemic views; the second part of the interview asked how students have changed their epistemic view and conceptual understanding about electricity.

Knowledge Test on Electricity. A knowledge test was designed to measure students’ conceptual understanding on electricity. The first part contained close-ended questions asking whether certain material (e.g., metal, lemon juice, graphite, distilled water, etc.) conducts electricity, the second part included open-ended questions asking students to explain the conductivity of different material, e.g., why do some material conduct electricity, and some do not? The first part of the test was scored according to the correctness of answers and the second part was coded based on scientifinness of ideas (Zhang, et al., 2007). Both parts of the test were transformed into percentage score and were averaged into an overall conceptual understanding score.

Knowledge Building Engagement. Students’ performance on Knowledge Forum was measured with a software Analytic Toolkit (ATK) developed by the Knowledge Building Research Team at the University of Toronto (Burtis, 1998). ATK could provide us quantitative measures such as number of notes created, percentage of notes linked and read, number of notes with scaffolds or keywords, etc.

We selected two measures: number of notes write and percentage of notes read to represent students' knowledge building participation and knowledge building awareness.

Conception of Collaborative Discourse. Students' conception of collaborative discourse was measured with an open-ended written test containing an item on "what is good discussion". Students were asked to fill out this test at the end of the program. A 3-point scale coding scheme was developed to capture the patterns of understanding. At level 1, students only focus on the behavioral aspects of discussion (e.g., *"try our best to discuss"; "people discuss carefully"*); at level 2, students mention about the importance of diverse ideas, questioning, or using new information for good discussion (e.g.,*"There are different ideas, questioning…in a good discussion."*); at level 3, students understand that a good discussion is a progressive and deepening process, involving questioning, emerging ideas, building on, and idea improvement (e.g., *"I think a good discussion should be like this: propose questions, answer the questions, different suggestions to the ideas/new understanding about the ideas, build on the previous ideas and make a even better idea. It keeps circulating….."*)

4. Analysis and Results

4.1 Effects of Knowledge Building on Epistemic View of Science

To examine the effects of knowledge building on students' epistemic view of science, a 2 x 2 (group x time) repeated measure MANOVA was conducted for all four components; the mean and standard deviation (SD) were presented in table 1. Results revealed statistically significant multivariate effects. The following univariate ANOVA showed significant main effect for time for role of idea F(1, 59)=7.459, p=.008, Partial eta^2=.112, suggesting that both classes improved over time on role of idea. There was also a significant main effect for group for role of idea F(1, 59)=6.987, p=.011, Partial eta^2=.106, and theory building F(1, 59)=6.393, p=.013, Partial eta^2=.100. Importantly, significant time x class was found for theory-fact understanding F(1, 59)=4.33, p=.042, Partial eta^2=.068, and social process F(1,59)=4.104, p=.047, Partial eta^2=.065. This indicated that knowledge building class improved more on their epistemic view on theory-fact understanding and social process of scientific progress than did the comparison class.

Table 1: Pre and posttest mean scores (SD in parentheses) in epistemic view across classes

	Knowledge building class(n=39)		Comparison class(n=22)	
	Pre-test	Post-test	Pre-test	Post-test
Role of Idea	1.24(.43)	1.39(.51)	.98(.31)	1.14(.34)
Theory-Fact	1.26(.72)	1.62(.75)	1.45(.60)	1.37(.49)
Theory Building	1.59(.64)	1.92(.87)	1.45(.51)	1.36(.49)
Social aspect	1.49(.76)	1.79(.73)	1.64(.66)	1.55(.51)
Epistemic overall	5.57(1.75)	6.72(2.13)	5.52(1.27)	5.41(.94)

4.2 Effects of Knowledge-building on Conceptual Understanding

Repeated measure ANOVA was conducted to examine the intervention effect on students' conceptual understanding. The mean and Standard Deviation of the pre and post conceptual understanding scores is .59(.08) and .70(.13) for knowledge building class, and .55(.07) and .59(.54) for regular class. The results showed significant main effect for time, F(1,57)=21.05, p=.000, Partial eta^2=.27, suggesting that both groups have improved their conceptual understanding over time. There was no main effect for group. Significant time and group interaction, F(1,57)=4.08, p=.04, Partial eta^2=.07, indicated that knowledge building group improved more on their conceptual understanding on electricity than did the comparison group.

4.3 Relationship among Epistemic View of Science, Conceptual Understanding, Understanding of Collaborative Discourse, and Knowledge Building Engagement

Correlation analysis was conducted within knowledge building group (n=39) (see table 2). Results showed that students' post epistemic view was correlated with their conception of collaborative discourse, Knowledge Forum awareness, and post conceptual understanding. It also showed that students' conception of collaborative discourse was significantly correlated with post conceptual understanding and Knowledge Forum awareness.

Table 2. Correlation among post overall epistemic view, post conceptual understanding, KF participation and awareness, and conception of collaborative discourse (n=39)

	Post epistemic	Post conceptual	Conception of discourse	KF participation	KF awareness
Post epistemic	1				
Post conceptual	.611**	1			
Conception of discourse	.677**	.417*	1		
KF participation	0.113	0.021	0.325	1	
KF awareness	.363*	0.212	.591**	.641**	1

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

Hierarchical regression (see table 3) was conducted for the both group (n=61), first entering prior science knowledge (prior conceptual understanding and academic science score), followed by pre epistemic view, and then learning context. Learning context was coded into two variables (Knowledge building group=1; comparison group=0). Results showed that prior science knowledge explained 12.6% of the variance, when pre epistemic view was added, additional 18.0% of the variance was explained. When learning context was added, additional 10.8% of the variance was explained. This indicated that over and above prior science knowledge, epistemic view and knowledge building context further contributed to post science knowledge.

Table 3. Hierarchical regression on post conceptual understanding with prior science knowledge, pre epistemic view, and learning context (n=61)

	R	R^2	R^2 Change	F Change	Sig.
Prior science knowledge & academic science score	.355	.126	.126	4.043	.023
Pre epistemic view	.554	.307	.180	14.317	.000
Learning context	.644	.414	.108	9.910	.003

5. The Epistemic and Conceptual Change Process

5.1 *Changed Epistemic Practice on Knowledge Forum*

To understand how students changed their understanding of the social process of scientific progress, we examined how they have experienced this aspect of inquiry in knowledge building. Therefore we examined students' collective discourse on Knowledge Forum, which was the place they might experience the social aspects of the inquiry. Meanwhile, interviews and classroom observation were also used to triangulate and enrich findings from the discourse data.

The knowledge-building students wrote 202 notes in total, and much of the notes were written during the class. Examination of students' earlier notes on Knowledge Forum showed that, students posted many fact-seeking or definition seeking questions in the beginning (e.g., "*can rubber conduct electricity*", "*what is conductor*", etc. they also answered some of these questions with intuitive opinions or undigested information from Internet. For example, a student asked: "*can we see electricity?*", another student responded and said: "*we can not see it*". No more response followed. Another example is, a student asked, "*what is conductor*", another student copied a definition from the textbook and said: "*conductor is a substance that conducts electricity*", that was the end of the discussion. These excerpts indicated that in the beginning students might regard scientific inquiry as a one-question-and-one-answer type of activity.

After the class on what is good discussion, students seemed to be more awareness of the progressive nature of inquiry and their discourse pattern started to shift in more sustained one. For example, student A initiated a question about whether electricity is hot, student B responded and said "*[my explanation/theory] when electricity pass through the conductor, it will generate heat, because of the existence of resistance*", the teacher further prompted: "*[I don't understand] why does it generate heat when there is resistance?*", Student C further explained and said: "*[my explanation/theory] when the free electron moves in certain direction with the electric force in the conductor, it keeps bumping on metallic ions, and transforms the energy into the ions. Therefore the ions moves more intensively, and cause the heat….*". This example showed how teacher scaffolded students to sustain the inquiry, and how students built on each other, and incorporated new information to address the problem and to deepen their understanding.

The most sustained thread was the one about wet wood conduct electricity. 44 notes had addressed and built on this problem. Students proposed different ideas and theories to explain the conductivity of wet wood. Some said that it couldn't conduct electricity; while others said "*it can, because water can conduct electricity*". A student further explained, "*the dry wood originally does not conduct electricity, however, after it was wet by the water, some of the impurity of the wood dissolved into water, the water is no longer pure any more, and can therefore become conductive. It is the water that conduct electricity, but not the wood*". As described in the instructional design session, to test these ideas, students designed experiment in groups. They found that dry wood could not conduct electricity, running water was a little bit more conductive, and salt water was most conductive. They started to wonder why salt water was more conductive and whether different kinds of water had different conductivity. Therefore they posted their emerging questions on Knowledge Forum again for further inquiry. This example showed that students' discourse pattern had started to shifted into more sustained one that reflected the progressive and emerging nature of inquiry.

5.2 Interpretation of the Epistemic Design of Knowledge Building

Qualitative analysis of students' interview transcripts indicated that how students interpret the design and their inquiry process might have influenced how they understand the nature of science, as the following excerpts illustrates:

> *I(interviewer): what are the new understandings you have about the nature of science after the knowledge building?*
> *Students Q: Develop new theory out of the existing theories.*
> *I: How?*
> *Student Q: If you discover a new problem, you can make an inference about the result of the problem according to existing theories.*
> *I: Why do you think like that?*
> *Student Q: Because science itself is a circulating process. After you solve a problem, you find another new problem, then you solve it and you find another new problem, it keep circulating.*
> *I: when did you start to think like this?*
> *Student Q: After the computer (Knowledge Forum) class*
> *Student M: Because in the first beginning we pose some questions and ideas in the initial view about electricity, later another new deepening view about electricity was created where we found the questions we posed earlier, and we raised more questions building on the responses of the original questions.*

It showed that these students have made the connection between their understanding about the "ever deepening and emerging" design features of knowledge building environment and their understanding about the progressive nature of science. It indicated that the epistemic feature of our designed learning environment might have influenced students' epistemic understanding.

Regarding how knowledge building helped them understand electricity better, some students mentioned about the importance of *taking over agency* in helping them improve their conceptual understanding, as a student reflected in the interview: "*knowledge building helps us understand things better. Because in the forum, we proposed many questions, and we search on Internet to find answers. Actually we were not just searching for answers, we also learned from the internet about why there is such kind of thing, and how it becomes this……*" This except also showed how knowledge building might help students expand and deepen their knowledge by let them aware of their own agency in the knowledge construction and knowledge creation process.

6. Discussion and Conclusions

This study designed of a computer-supported knowledge-building environment and examined its role on students' epistemic and conceptual growth. The first research question asked about the effects of the design on students' epistemic and conceptual understanding, quantitative analysis was conducted and it showed that knowledge-building students improved more on epistemic view of science and conceptual understanding compared with the traditional group. To address the second research question, correlation analysis was conducted and results showed that students' epistemic view of science was highly correlated with conception of collaborative discourse, which indicated that the better students understand their own collaborative knowledge building process, the better they may conceive scientists' collective theory building process. Further regression analysis indicated that both knowledge building environment and post epistemology of science predicted students' post conceptual understanding. These quantitative findings were consistent with the previous studies on the effects of knowledge building on epistemic and conceptual understanding (Chan & Lam, 2010), and on the relationship between epistemic cognition and conceptual change (Qian & Alvermann, 1995; Stathopoulou & Vosniadou, 2007), and we further related these constructs to conception of collaborative discourse, and extended the research on epistemic view to the social-cognitive perspective.

The third research question asked the change process of epistemic view and conceptual understanding. Qualitative analysis of students' Knowledge Form discourse showed that the structure of students' discourse shifted from "one question and one response" type of pattern to more sustained and progressive one, which indicated that students' epistemic practice became more sophisticated over time. Meanwhile, qualitative analysis of students' interview showed that students' interpretation of the epistemic design of the knowledge building influenced how they understand the nature of science and learning, which accordingly changed their conceptual understanding about electricity.

This study showed the possibility of changing young students' epistemic view of science with computer-supported knowledge building design. It also showed how students' experience with knowledge building and reflection of this process might have helped them understand the nature of science better. This study contributed to our understanding about way we could embed epistemology components in technology and learning environment design to improve students' epistemic and conceptual understanding. It indicated that if we embed the epistemic feature, such as "deepening", "progressive", and "emerging", in the technology-supported learning environment, students might start to aware of the collective and progressive nature of scientific inquiry through engaging in it and reflecting about it.

This study is only the first iteration of an intervention project. Students' epistemic reflection of their inquiry process was not well scaffolded, future study could be conducted to further improve the design by letting students reflect on the epistemic implication of their experience, and helping them make the connection between their inquiry process and scientists' inquiry process. It was a short intervention, the sample size was small, and the comparison group was not equivalently controlled. The inferences made about the effects of the learning environment should be carefully interpreted; future studies could be designed with longer duration, larger sample size, and better controlled comparison group, to further test the theory. Meanwhile, the mechanism of the knowledge building process could also be further unpacked to provide a richer understanding about the relationship between knowledge building dynamics, epistemic view of science, and conceptual understanding.

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