Received: 28 July 2016 | Revised: 25 January 2018 | Accepted: 12 March 2018

DOI: 10.1111/jcal.12261

ORIGINAL ARTICLE

WILEY Journal of Computer Assisted Learning

Examining the role of computer-supported knowledge-building discourse in epistemic and conceptual understanding

Feng Lin[1] | **Carol K.K. Chan**[2]

[1] Wisconsin Center for Educational Research, University of Wisconsin-Madison, Wisconsin, USA

[2] Faculty of Education, The University of Hong Kong, Hong Kong

Correspondence
Feng Lin, Wisconsin Center for Educational Research, University of Wisconsin-Madison, 1025 West Johnson Street, Room 665, Madison, Wisconsin 53706, USA.
Email: feng.lin@wisc.edu

Abstract

This study characterized students' online collaborative discourse from a theory-building perspective and examined its relation to epistemic and conceptual understanding. Fifty-two fifth graders' Knowledge Forum discussions on electricity were analysed. Discourse moves were coded within the inquiry threads, and two key epistemic patterns were identified: problem-centred uptake and theory-building moves. Analysis showed that higher-quality discourse threads included more problem-centred uptake moves in which ideas were built more coherently on each other to address the central problem. There were also more theory-building moves on explanation and sustain inquiry. We also examined the relationship between discourse moves and conceptual-epistemic understanding. Regression analyses showed that problem-centred uptake predicted epistemic cognition beyond prior epistemic cognition and that theory-building moves on explanation predicted students' conceptual understanding beyond their prior science understanding. Implications for fostering more productive discourse and sophisticated epistemic cognitions using online discussion are discussed.

KEYWORDS

collaborative online discourse, conceptual understanding, epistemic cognition, knowledge building

1 | INTRODUCTION

Understanding collaborative online discourse is a central issue in computer-supported collaborative learning (CSCL). Examining collaborative online discourse depends on how we look at collaboration and learning as well as the frameworks we employ (Hmelo-Silver & Bromme, 2007). Many existing studies conceptualize collaborative discourse as argumentation emphasizing social cognitive conflict, justification, and persuasion and consensus (Chiu, 2008; Felton & Kuhn, 2001; Golanics & Nussbaum, 2007; Lu, Chiu, & Law, 2011; Nussbaum, 2008; Weinberger & Fischer, 2006) or as a convergence process focusing on social negotiation and shared understanding (Fischer & Mandl, 2005; Gunawardena, Low, & Anderson, 1997; Hewitt, 2001). Few studies have conceptualized collaborative discourse as theory building and have focused on the epistemic aspects of discourse moves. This perspective, we argue, is especially important for understanding students' collaborative inquiry and learning in science.

Science is primarily about generating knowledge and constructing deeper explanations of the natural world (Carey, Evans, Honda, Jay, & Unger, 1989). It is not an individual endeavour but is a collective theory-building process involving progressive discourse that consists of the pursuit of questions, deepening explanations, and the synthesis of ideas and theories (Bereiter, 2016). Scientific progress is a dialectic process that involves thesis, antithesis, and synthesis that repeats over time, generating theories that progress to higher levels (Bereiter, 1994). Science educators advocate educating the next generation's scientists by engaging students in authentic science practices. Theory building, as a central scientific practice, is an important lens through which to understand students' inquiry process and science learning.

Various forms of computer-assisted platforms have emerged to support interaction and collaborative discourse. Knowledge Forum® (KF) is a principle-based and CSCL environment, designed to support students' theory-building and community knowledge advancement (Scardamalia & Bereiter, 2006). Many studies on the nature of KF discourse have focused on social and cognitive aspects as analysis of principles (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007), connectedness and collective responsibility (Hong, Scardamalia, Messina, & Teo, 2015), and discourse patterns (Fu, van Aalst, & Chan, 2016). There has been some interest in epistemological inquiry (Hakkarainen & Sintonen, 2002) and epistemic outcomes (Chen, 2017), but few studies have systematically examined the epistemic aspect of students' KF theory-building process. This study examined young students' collaborative discourse on KF from theory-building and epistemic perspectives, to understand how children practice science like mature scientist communities; that is, how they initiate inquiry, build on each other's ideas, sustain inquiry, and work collectively towards progressive problem solving and knowledge creation, mediated through technology. In addition, this study also investigated the relationship between KF discourse and students' epistemic and conceptual understanding.

2 | LITERATURE REVIEW

2.1 | Computer-supported knowledge building discourse

Knowledge building is a computer-supported educational model emphasizing students taking collective cognitive responsibility for community knowledge advancement (Scardamalia & Bereiter, 2006, 2014). Ideas are treated as improvable conceptual artefacts (Bereiter, 2002), and students take responsibility and agency to pursue the creation and improvement of ideas that add value to the community (Zhang et al., 2007). To support these knowledge-building processes, KF has been developed. It provides a multimedia community knowledge space wherein students can pursue ideas collaboratively to advance community knowledge in much the same way as mature research communities do (Scardamalia, 2004). KF scaffolds students to develop and publish their ideas (as an author or co-author), and link, revise, and reorganize these ideas. KF is primarily constituted of views and notes which serve as collaborative inquiry spaces for organizing notes and improving ideas. In Figure 1, the small square icons represent students' notes, and the lines between icons are the build-on relationship between notes. Figure 2 shows an example of a note. The scaffolds (e.g., *I need to understand*; *my theory*;

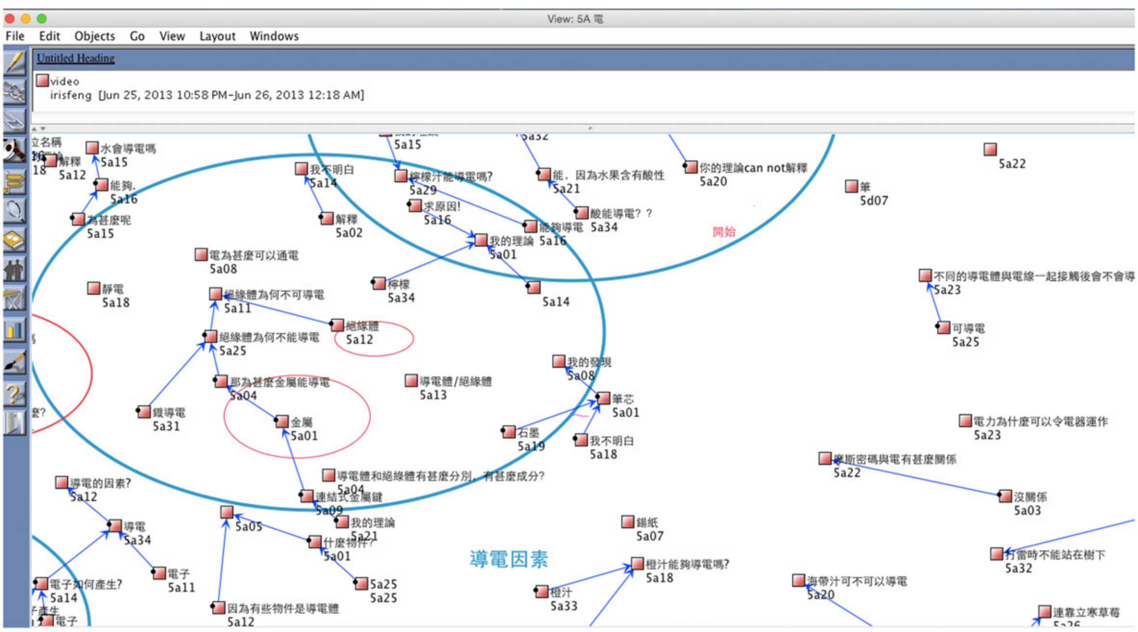

FIGURE 1 An example of a view on Knowledge Forum [Colour figure can be viewed at wileyonlinelibrary.com]

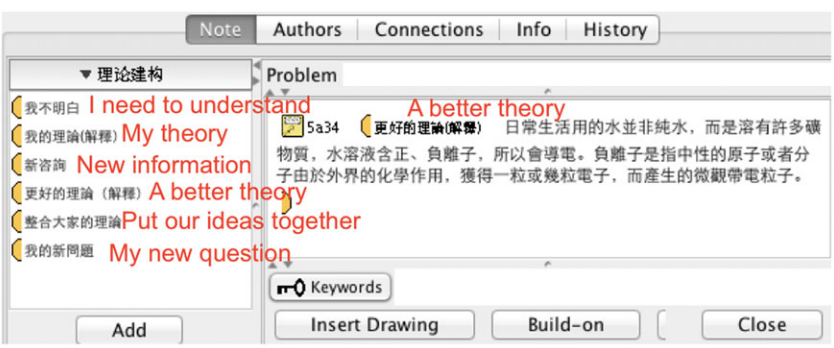

FIGURE 2 An example of a note and scaffolds on Knowledge Forum [Colour figure can be viewed at wileyonlinelibrary.com]

new information; and *a better theory*) are prompts students can choose to support their theory-building process.

Examining and analyzing knowledge building discourse on KF is central to knowledge building research (Scardamalia & Bereiter, 2006; Zhang et al., 2007). Some researchers have used social network analysis to visualize the quantitative interaction in knowledge-building discourse (Chen, Scardamalia, & Bereiter, 2015; Oshima, Oshima, & Matsuzawa, 2012), some used qualitative content analysis to examine discourse quality and patterns (Lipponen, 2000; Zhang et al., 2007), and some used mixed methods to quantify qualitative discourse analyses (Lee, Chan, & Aalst, 2006; Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015). Hakkarainen's (2003) “questions and explanations” framework is widely used to analyse knowledge-building discourse (e.g., Lee et al., 2006) and allows researchers to code and count the depth of questions and explanations in the inquiry and relate them to students' learning (Hakkarainen & Sintonen, 2002; Lee et al., 2006; Zhang et al., 2007). However, this framework falls short in unpacking discourse interactions and in identifying conceptual connections among ideas (e.g., how coherent later ideas are linked to previous ideas). As CSCL trends emphasize connected discourse, knowledge-building discourse research has shifted to analysing KF inquiry threads and notes for emergent theory-building and knowledge advances informed by knowledge-building principles (Zhang et al., 2007).

Premised on Bereiter and Scardamalia's knowledge-building model, van Aalst (2009) distinguished between three modes of discourse: knowledge sharing, knowledge construction, and knowledge creation. Knowledge sharing involves knowledge transmission, and people share information and opinions without much processing. Knowledge construction involves cognitive processing (e.g., metacognition, interpreting, and evaluating new information), and students interact to process information and ideas deeply. In knowledge creation, new understandings and ideas emerge from collective inquiry. Ideas are treated as improvable conceptual artefacts, and the community works together, continually identifying gaps and engaging in inquiry. These different discourse modes reflect different degrees of knowledge building and advancement.

Despite the growing interests in understanding the interaction and collective aspects of the discourse, less is known about how the discourse moves are related to the collective knowledge advancement of the community. In this study, we characterized students' discourse moves from an epistemic and theory-building perspective as well as examined the relationship between discourse moves and collective knowledge advancement. Specifically, building on van Aalst's (2009) work, we coded discourse threads (threads of notes that are physically connected) constructed by a group of students to depict different degrees of conceptual quality and collective knowledge advancement and examined how the proportion of discourse moves might differ in these discourse threads.

2.2 | Epistemic cognition in science and knowledge building discourse

Epistemic cognition in science is concerned with how people think about the nature of knowledge and knowing in science (Elby, Macrander, & Hammer, 2016; Greene, Sandoval, & Bråten, 2016). Sophisticated epistemic cognition in science is an important goal of science education and is related to students' learning and reasoning (Chinn, Buckland, & Samarapungavan, 2011). Elby et al. (2016) discussed how epistemic cognition in science stems largely from two traditions of research: personal epistemology and the nature of science (NOS). The former originates from the psychological tradition (Hofer & Pintrich, 1997; Schommer, 1990) and examines students' epistemological beliefs including such dimensions as source, certainty, development, and justification of knowledge (Conley, Pintrich, Vekiri, & Harrison, 2004; Elder, 2002). The second tradition, the NOS, stems from discussions about the goals of science education and is informed by philosophy and sociology of science. The examined NOS aspects include the empirical, creative, and imaginative nature of science along with the theory-laden and social-cultural aspects of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Tsai, 1999).

Related to these two traditions, another particular strand examines children's understanding of science from a constructivist and role-of-idea perspective (Carey et al., 1989; Smith, Maclin, Houghton, & Hennessey, 2000), that is, variously seeing science as concrete, tentative, or constructing explanations for their understanding of the world. Some researchers (Chuy et al., 2010) from this perspective also emphasize the theory-building nature of science and identify four dimensions of epistemic views: nature of scientific progress, theory–fact understanding, role-of-idea in scientific progress, and invention. This study followed this line of research and examined students' epistemic cognition in science from a role-of-idea and theory-building perspective.

One of the key goals of this study is to examine the relationship between knowledge-building discourse and epistemic and conceptual understanding. Substantial research in science has shown how more-sophisticated epistemic cognition is related to conceptual understanding (Mason, 2010; Stathopoulou & Vosniadou, 2007); students who believe knowledge is changeable are more likely to engage in deeper processing, leading to better conceptual understanding. Many studies have also examined the role of knowledge-building discourse in conceptual understanding, and research has shown that students' online knowledge-building discourse which was characterized by level of inquiry and explanations predicted their science understanding (Lee et al., 2006). However, specific investigation on the relations of epistemic cognition from a theory-building perspective with student's conceptual understanding and systematic examination on the relationship between knowledge-building discourse, epistemic cognition, and conceptual understanding are still lacking.

There are now increasing research interests in examining students' epistemic cognition through the lens of discourse (Knight & Mercer, 2017; Scherr & Hammer, 2009). For example, Knight and Mercer (2017) examined the relationship between epistemic cognition and information-seeking in the context of collaborative discourse and identified epistemic moves associated with learning outcomes. Rosenberg, Hammer, and Phelan (2006) analysed students' discourse, to examine the nature of epistemological understanding and coherence. Scherr and Hammer (2009) explored how students' behaviour and discourse reflected their epistemic framing. Although various studies examined epistemic cognition from the lens of classroom discourse, there have been few studies investigating the relations between online collaborative discourse moves and students' explicit epistemic cognition.

In the knowledge building research tradition, as discussed above, there have been major research efforts toward analysing discourse patterns and their relationship with conceptual understanding. There has also been some interest in examining discourse as epistemological inquiry (Hakkarainen, 2003) and the influence of knowledge building environment on students' epistemic cognition (Chen, 2017; Hong & Lin, 2010; Lin & Chan, 2018). Hong, Chen, and Chai (2016) examined how college students with more or less sophisticated epistemic cognition differed in their KF discourse, indicating that KF discourse impacts epistemic cognition. However, few studies have specifically investigated how KF discourse moves might contribute to students' explicit epistemic cognition, particularly among elementary school students.

Therefore, in this study, we will examine the relationship between KF discourse, explicit epistemic cognition, and conceptual understanding. To this end, we will first characterize students' KF discourse from an epistemic and theory-building perspective and then examine whether these characterized KF discourses are related to students' epistemic and conceptual understanding. We hypothesize that students' engagement in theory-building discourse will contribute to students' epistemic understanding of science as a collective theory-building process and their conceptual understanding in science.

Three research questions were addressed in this study: (a) What characterizes students' discourse moves in KF, and how do they differ in discourse threads of high and low knowledge advancement? (b) How do discourse moves predict epistemic understanding of science? And (c) How do discourse moves predict conceptual understanding in science?

3 | METHOD

3.1 | Participants and context

The participants in this knowledge-building environment were 52 fifth graders (aged 10–11) from two classes in the same school (Class 1, 13 boys, 20 girls; Class 2, 10 boys, 9 girls) located in a low-income area of Hong Kong. Two different teachers taught the same science topic on electricity and conductors; they used the same pedagogy and material and jointly designed the program with the researchers.

3.2 | Procedure

The program was conducted in 11 sessions (40 min each) over 3 months. Both classes were designed based on knowledge-building pedagogy and epistemic reflection using KF. The students posed problems, questions, and explanations on KF to advance community knowledge. The design encouraged the students to reflect on their inquiry processes and to compare their inquiry with mature scientific inquiry. The 11 sessions included classroom inquiry in related to science concepts, the teachers' instruction on using KF features, students' experimentation and discussion in the classroom, and students writing on KF.

The knowledge-building environment design supported by KF included several features: The first was concerned with activating prior understanding. Students discussed their initial ideas about electricity and inquired into what scientists do. The second feature was about authentic problems and inquiry. The students watched experiments about materials conducting electricity which triggered their wonderment; then, they posed ideas and questions on KF. The students could use KF features when posing ideas and writing computer notes on KF (Figure 2). For example, when they start a note, they could select relevant scaffolds (e.g., I need to understand, my theory, and new information) to help structure their writing and inquiry. These scaffolds were explained by the teacher and discussed in class to facilitate students' theory-building discourse. The third feature involved deepening their inquiry through experiments and classroom epistemic talk based on KF writing. The students designed and conducted group experiments and continued working on KF to improve their ideas. The teachers scaffolded students to reflect on their forum discourse. They started with initial "views" (discussion area), and then deepening views on KF were created for emerging questions. KF discussions were asynchronous. The students worked both in class and after class on KF, and online and offline discourse were integrated. Both classes worked in their own classroom and respective KF discussion views. The materials and media of communication were in Chinese.

3.3 | Data source

3.3.1 | Written test of epistemic cognition in science

Students completed a paper-and-pencil written test on epistemic cognition in science that assessed their understanding of the nature of science. The written test, lasting for about 30 min, was administered by the researchers before and after intervention (pre- and posttests). The test consisted of eight written questions adapted from previous studies (Carey et al., 1989): What is science? What do scientists do? How do scientists do their work? Why do you think scientists do experiments? What is the relationship between theory and fact? How do you think new scientific theories are developed? Do you think scientific theory ever changes, and why? And, do you think it is good for science if scientists have different or even contradictory ideas?

All eight questions were scored using a common framework, and each question was scored using a specific coding scheme for specificity (an example was shown in Table 1).

The framework consists of four levels: Level 1 responses view science as a set of concrete activities; Level 2 responses show some vague understanding of abstract entities; Level 3 responses show some connection between ideas and experiments; and Level 4 responses show students' understanding of the relationship between ideas and experiments, theory revision, and the progressive nature of science (see Table 1). Several questions related to the same theme were combined, and four dimensions were extracted: (a) role-of-idea, (b) theory revision and creation, (c) theory–fact understanding, and (d) social process for scientific progress (Lin & Chan, 2018). Scores on different questions tapping the same dimension were combined and averaged to form a dimension score (range 0–4). The four dimension scores were added up to form an overall score on epistemic cognition in science (range 0–16).

The first author coded all data. A second rater who was specialized in a similar area was trained and independently coded 30% of the data. Disagreements were resolved through discussion. Cohen's Kappa results indicated good interrater reliability: role-of-idea, $K = .86$; theory–fact understanding, $K = .72$; theory revision, $K = .84$; and social process, $K = .82$.

TABLE 1 Coding scheme for epistemic cognition (an example on "what do scientists do?")

Coding level	Coding description	Examples of responses
Level 0	Missing or irrelevant responses	"Do not know"
Level 1	Focus on scientists work as concrete activities	"Invent different things" (Post5D04)
Level 2	Vague sense about abstract unseen entities in science.	"Ask question, experiment, hypothesis, theory" (post5D18)
Level 3	Some understanding about the relations between theory and experiment.	"I think scientists do experiments to deny or support some idea." (5a32)
Level 4	Understanding about the role of idea and theory in science.	"…. I think what scientists do is like a cycle. They start with a question. They work together to solve the problem … revise the theory, and constantly improve it. It keeps circulating." (Post5A16)

3.3.2 | Knowledge test for conceptual understanding

Students worked on a paper-and-pencil written test that assessed their science knowledge and conceptual understanding of electricity. The test lasted for 20 min and was administered by the researchers in class, before and after the intervention (pre- and posttests). The test assessed students' science understanding and explanation (e.g., why water is/is not a conductor) and generation of questions about electricity. Their responses to the former were coded on a 4-point scale reflecting the scientific quality of responses (Zhang et al., 2007), and the latter were coded based on depth of questions (Lee et al., 2006). The first author coded all data. A second rater independently coded 30% of items, and differences were resolved in discussion; interrater reliability of .80 (Cohen's Kappa) was obtained.

3.3.3 | KF writing: Discourse threads for collective knowledge advancement

Students' collective knowledge on KF was coded using discourse threads. We first parsed students' KF discussions undertaken over the 3 months into threads of notes addressing shared problems in a community knowledge space (Zhang et al., 2007). Each thread was a discussion episode and was scored on a 4-point scale adapting from van Aalst (2009) and Fu (2014). We then coded threads of notes to depict different degrees of conceptual quality and knowledge advancement.

Level 0: Fragmented discussion (no knowledge advancement). Ideas expressed were isolated, with little or no connection to others. No specific problem was focused on.

Level 1: Knowledge sharing (low knowledge advancement). Knowledge quality was low. Ideas and information were shared, but with limited knowledge advancement. Discourse threads show notes with interactions that share opinion and information from books/internet; intuitive ideas were posed without explanation or evidence (Fu, 2014) (see Table 2).

Level 2: Knowledge construction (medium knowledge advancement). Knowledge quality is medium with minor knowledge advancement. Discourse threads show notes with interactions and constructive processes using build-on, elaboration, inferences, and explanation to create joint understanding (see Table 3).

Level 3: Knowledge building (high knowledge advancement). Knowledge quality is high showing knowledge advancement. Discourse

TABLE 2 An excerpt of a knowledge-sharing (Level 1) discourse thread

Student #	Note content
5a16	[I need to understand], can Dead Sea conduct electricity?
5a18	Yes
5a01	[I need to understand], why can the Dead Sea conduct electricity?
5a32	The Dead Sea can conduct electricity
5a20	Salt
5a16	The reason why it is called Dead Sea is that its high salinity cannot make fish survive.
5a16	I think it can conduct electricity

TABLE 3 An excerpt of a knowledge-construction (Level 2) discourse thread

Student #	Note content
5d07	Why is water a conductor?
5d20	Water has some components that conduct electricity
5d02	[I need to understand] what are the components that conduct electricity?
5d11	Because water has some impurities.
	....
5d08	If water is pure, with no impurities, it would be a kind of insulator; but as long as it has impurities, especially something like salt dissolved in it, it will become a conductor.

threads reflect knowledge building that involves progressive idea development, collective attempts to move beyond current knowledge, and contribution from different community members (see Table 4).

The first author coded all data and identified 28 KF discourse threads (including such themes as why does salt/salt water conducts electricity, what is a semiconductor, and why do fruits/juice conduct electricity). A second rater coded 30% of the threads. Cohen's Kappa was .84, indicating good interrater reliability.

3.3.4 | KF Writing: Discourse moves

Analyses of individual notes were conducted to examine discourse moves within inquiry threads, from a theory-building perspective. Although they were examined individually, they were considered in situ as part of the entire thread. The unit of analysis was *individual note within the physical thread*, meaning that notes were coded individually, but their physical level in the inquiry threads was considered. Figure 3 shows how the physical levels of a complete KF thread were defined. The original question represents Level 1, a response to this note is Level 2, a response to a Level 2 note is Level 3, and so on. This allowed us to track the sequences of ideas in physical threads and to assess the coherence of idea interaction. During the analytic process, we sorted all notes in an Excel file and labeled their physical levels. Two key discourse move types were identified, and all KF notes were double coded for both discourse types.

Problem-centred uptake moves

This discourse move is about how ideas are progressively and coherently developed to problematize and to address previous ideas. Scientific and epistemic inquiry is problem-focused; problem-centred discourse moves have been identified as important in students' dialogue for conceptual change (Chan, 2001). A key characteristic of knowledge-building is students working on progressive problem solving (Scardamalia & Bereiter, 2014). We adopted the interactional

TABLE 4 An excerpt of a knowledge-building (Level 3) discourse thread

Student #	Note content
5a03	[I need to 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 cannot conduct electricity
5a20	[You theory cannot explain]: After this experiment, we found that salt cannot conduct electricity, but salt water can. Salt water is NaCl, it is an ionic compound; there are free electrons or ions in it…so it can conduct electricity.
5a34	[A better theory]: because salt consists of Na + and Cl-, Na + is metal ion, and can allow free electron to pass through. Na + and K+ transmit to nerves in our brain, therefore salt can conduct electricity.
5a31	[I need to 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 an electrolyte can conduct electricity.

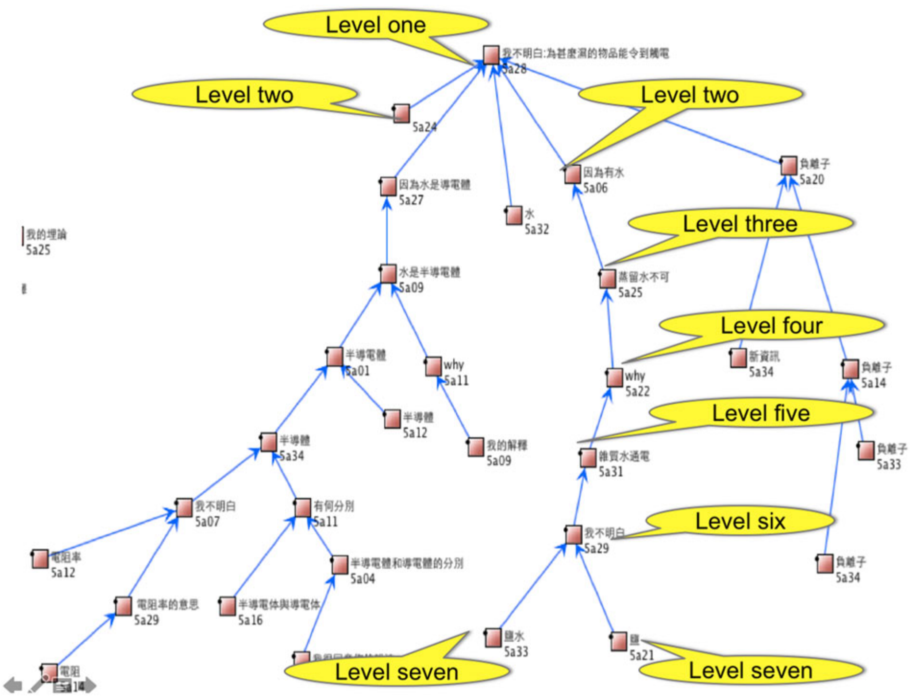

FIGURE 3 An example to illustrate a Knowledge Forum physical thread with notes at different physical levels [Colour figure can be viewed at wileyonlinelibrary.com]

analysis term "uptake" (Suthers, Dwyer, Medina, & Vatrapu, 2007) to describe the "act of a participant taking reifications of prior or ongoing participation … as having certain relevance for further participation" (p. 696). Uptake focuses on social dimensions, and we elaborate it to include epistemic aspects—problem-centred uptake—to reflect how students problematize collective knowledge, track problems, and coherently address ideas in problems.

Four levels of problem-centred uptake notes were identified. Level 1 notes made no connection or a weak connection to the previous note (e.g., irrelevant response and simply saying yes/no). Level 2 notes showed a vague connection, which was not essential to solving the problem (e.g., asking for elaboration and offering simple explanation). Level 3 notes had clear and reasonable connections to previous notes (e.g., building connections and asking for explanation). Level 4 notes showed coherent connection to previous notes and were important for tackling and solving the problem (e.g., avoiding closure; deepening; and refocusing the discussion). Notes were contextualized and coded with consideration to their physical levels.

Knowledge building emphasizes problem-centred discourse and often discourse threads begin with a problem. Our analysis on problem-centred uptake could help tap into whether students can make connections to the previous notes and reflect whether they attempt to address community needs for solving problems. Students may or may not be able to solve the problems, just as scientists may not solve complex problems after years; but the attempts to connect to previous notes (connect to others' work) is an important part of problem solving and epistemic practice.

Two raters independently coded 30% of the problem-centred uptake notes, obtaining an interrater reliability of $K = .84$ (Cohen's Kappa).

Theory-building moves

Theory-building moves refer to the different roles the notes play in theory-building processes. Scientific inquiry and theory-building involves initiating a problem, asking questions, constructing explanation, deepening explanation, theorizing, and sustaining emerging inquiry. Qualitative analyses, using bottom-up and top-down interactive approaches, identified eight key theory-building moves (see Table 5): (a) initiate inquiry (low), fact-seeking questions/statement; (b) initiate inquiry (high), explanation-seeking questions; (c) explanation (low), general and intuitive explanation; (d) explanation (high), theorizing and searching for mechanism; (e) sustain inquiry (low), asking elaborate questions; (f) sustain inquiry (high), asking emerging and deepening questions; (g) cognitive conflict, disagreement, and refutation; and, (h) nonbuild-on. Table 5 shows the definition, and Table 6 provides specific examples for these different types of theory-building discourse moves in a discourse thread. Discourse moves based on KF notes were coded from the 28 discourse threads. The first author coded all data and identified eight categories of theory-building moves. A second-rater independently coded 30% of the notes. Cohen's Kappa was .97, indicating very good interrater agreement.

4 | ANALYSIS AND FINDINGS

4.1 | Background information

The general effects of the designed learning environment on epistemic and conceptual understanding are reported to provide contextual information. Paired-sample *T*-tests showed Classes 1 and 2 students improved in conceptual understanding at statistically significant levels (pretest, $M = 0.25$, $SD = 0.08$; posttest, $M = 0.56$, $SD = 0.14$; $t = -11.602$, $p < .001$, Cohen's $d = -2.72$) and (pretest $M = 0.25$, $SD = 0.10$; posttest $M = 0.51$, $SD = 0.14$; $t = -6.49$, $p < .001$, Cohen's $d = -2.14$), respectively. Students' improvement in epistemic cognition was also statistically significant (pretest, $M = 6.99$, $SD = 1.15$; posttest $M = 9.92$, $SD = 1.75$; $t = -9.84$, Cohen's $d = -1.98$) and (pretest $M = 6.22$, $SD = 1.77$; posttest $M = 8.14$, $SD = 2.08$; $t = -3.157$, $p = .005$, Cohen's $d = -.99$), respectively. These results indicate that both classes experienced changes in epistemic and conceptual understanding after the knowledge-building instruction.

Class 1 students wrote 449 notes on KF. On average, students wrote 13.2 notes each, read 30.4% of their peer's notes, used 11.7 thinking prompts, and made 1.6 revisions; a total of 66.7% of notes were linked (connected) to other notes. Class 2 wrote 202 notes. On average, students wrote 7.5 notes, read 32%, used 9.9 thinking prompts, and made 1.5 revisions. A total of 52.7% of notes were linked. With the exception of productivity, the two classes are comparable on major KF participation indices, particularly those pertaining to collaboration (e.g., notes read and linked). These participation levels are also generally comparable with those reported in similar studies (Lai & Law, 2006). Both classes used similar knowledge-building

TABLE 5 Coding scheme for theory building moves

Code	Description
Initiate inquiry (low)	Initiates a thread with fact-seeking question or a statement
Initiate inquiry (high)	Initiates a thread with explanation-seeking question
Explanation (low)	Provides general and intuitive reasons for the phenomena using simple statements or paraphrases information
Explanation (high)	Constructs elaborated responses to theorize and to explain; conjecturing mechanisms for phenomena, incorporating new information
Sustain inquiry (low)	Asks simple or superficial questions to continue the discussion
Sustain inquiry (high)	Sustains the inquiry with deepening questions; engages in progressive problem solving
Cognitive conflict	Shows disagreement to other ideas; refutes different viewpoints
Nonbuild on	Scattered notes without any build-on; or other irrelevant notes

TABLE 6 An example of coding for theory-building discourse moves

Note #	Student #	Note content	Physical level	Theory-building moves
#1	5a28	[I need to understand]: why can wet stuff get people an electric shock?	1	Initiate inquiry (high)
#2	5a06	[My theory]: because of water	2	Explanation (low)
#3	5a25	[Your theory can not explain]: if it is distilled water, then it cannot conduct electricity, because it is distilled.	3	Cognitive conflict
#4	5a22	[I need to understand]: why?	4	Sustain inquiry (low)
#5	5a31	[My theory]: because only impure water can conduct electricity	5	Explanation (low)
#6	5a29	[I need to understand]: which kind of impure water can conduct electricity?	6	Sustain inquiry (high)
#7	5a33	Salt water	7	Explanation (low)
#8	5a21	Salt	7	Explanation (low)
#9	5a27	[My theory]: because water is a conductor	2	Explanation (low)
#10	5a09	[My theory]: water is not a conductor. It is semiconductor.	3	Cognitive conflict
#11	5a01	[I need to understand]: why is water a semiconductor? What is semiconductor?	4	Sustain inquiry (low)
#12	5a34	[my theory] a semiconductor has resistivity that is between an insulator and metals …	5	Explanation (high)
#13	5a07	[I need to understand] what is resistivity?	6	Sustain inquiry (low)
#14	5a29	[My theory] a material that has a low resistivity is called conductor, the common conductor is metal, but the best conductor is silver. ….	7	Explanation (low)
#15	5a14	[I need to understand] how do we know which material has a higher or a l ower resistance?	8	Sustain inquiry (high)
#16	5a20	[A better theory]: the water we use in our daily life is not pure water. It has some minerals in it, and contains positive and negative ions. Therefore, it can conduct electricity. The negative ions come from the neutral atoms that gain electrons due to the chemical reaction outside.	2	Explanation (high)

designs, the teachers codesigned all lessons with the researchers, and the students all had the same instructional time. Together with the information on the patterns of preposttest change, these two classes are considered comparable in providing data for discourse analysis in relation to epistemic and conceptual change. To increase the power of analysis, the two classes were combined for analysis. Of the 52 students, one was excluded from the analysis as an outlier based on initial data analysis related to prior conceptual understanding scores.

Both classes in total wrote 651 KF notes. Data checking was conducted to identify the notes relevant for discourse analysis. For all the KF notes written, some are unrelated notes (not related to electricity discussion), and some are individual portfolio (summary) notes on what they learned. Because the current study mainly focuses on knowledge-building discourse, we did not include those unrelated and portfolio notes and only analysed students' discussion about electricity (475 notes).

4.2 | Research Question 1: Discourse moves and collective knowledge advancement

Question one examined the characterization of discourse moves and their relations with collective knowledge quality and advancement. KF discourse threads were analysed using a 4-point coding scheme to identify the extent of knowledge advancement. We identified 28 discourse threads, ranging from low- to high-knowledge quality, including 2 fragmented discussion, 9 knowledge-sharing, 13 knowledge-construction, and 4 knowledge-building discussions threads (episodes). Table 7 shows the descriptive information on frequencies and percentages of different discourse move types for the different knowledge-building thread levels.

Analyses were conducted to investigate how the occurrence of discourse moves varied in discourse threads that depicted different levels of knowledge quality and advancement. To control for frequencies in discourse threads of different lengths (i.e., loner threads have more occurrence of discourse moves), we examined the proportions rather than frequency counts. We categorize the four types of threads into two major groups (fragmented and sharing as low versus knowledge-construction and knowledge creation as high) to illustrate students' collective work in discourse of high- versus low-conceptual quality. We then performed Chi-squared tests of homogeneity of proportions using RStudio to compare the proportion of high-level problem-centred uptake between high-level (n = 17) and low-level (n = 11) threads. The results showed that high-level discourse thread differed from the low-level ones on proportion of high-level problem-centred uptake moves (χ^2 = 51.952, df = 1, p < .001). The p values were adjusted using the Bonferroni–Holm method to account for cumulative error.

Similarly, we also conducted Chi-squared tests of homogeneity of proportions to compare the proportion of different kinds of theory-building moves between high- and low-level discourse patterns. The results showed that there were significant differences in proportions of sustain inquiry (low)(χ^2 = 5.351, df = 1, p = .02), sustain inquiry (high)(χ^2 = 8.592, df = 1, p = .003), and explanation (high)(χ^2 = 14.097, df = 1, p < .001). There were no significant differences on initiate inquiry (low), initiate inquiry (high), explanation (low), or cognitive conflict. The p values were adjusted using the Bonferroni–Holm method.

These results indicate that in high-level discourse threads (more collective knowledge advancement), ideas were more coherently built upon each other to address the inquiry problem, and there were more efforts to sustain the inquiry and develop elaborated explanations.

TABLE 7 Frequencies of discourse moves in Knowledge Forum discourse threads of high-low knowledge advance

Discourse threads (# of threads)	# and % of high-level uptake (Levels 3 & 4)	# and % of theory-building moves							
		Initiate inquiry (low)	Initiate inquiry (high)	Sustain inquiry (low)	Sustain inquiry (high)	Explanation (low)	Explanation (high)	Cognitive conflict	Non build-on
Fragmented discussion (2)	0 (0%)	4 (7.4%)	3 (5.5%)	0 (.00)	2 (3.7%)	7 (13.0%)	1 (1.9%)	1 (1.9%)	36 (66.7%)
Knowledge sharing (9)	6 (6%)	9 (8.6%)	8 (7.6%)	5 (4.7%)	3 (2.9%)	42 (40%)	6 (5.7%)	4 (3.8%)	28 (26.7%)
Knowledge construction (13)	59 (31%)	7 (3.6%)	16 (8.3%)	26 (13.5%)	20 (10.4%)	39 (20.3%)	38 (19.8%)	10 (5.2%)	36 (18.8%)
Knowledge building (4)	49 (40%)	13 (10.5%)	10 (8.1%)	4 (3.2%)	17 (13.7%)	36 (29.0%)	16 (12.9%)	16 (12.9%)	12 (9.7%)

4.3 | Research Question 2: Discourse moves and epistemic understanding of science

The second and third research questions examine how the identified discourse moves predict students' epistemic understanding of science and conceptual understanding. We first conducted correlation analysis to examine what discourse moves were related to epistemic understanding. Based on this information, we then conducted hierarchical regression analysis to examine if these discourse moves were significant predictors of epistemic and conceptual understanding.

Correlation analysis

Table 8 shows that students' epistemic cognition scores were statistically significantly correlated with high-level problem-centred uptake (r = .339), explanation (high)(r = .292) and sustain inquiry (high)(r = .286) discourse moves scores. As well, conceptual understanding was statistically significantly correlated with epistemic cognition (r = .489), high-level problem-centred uptake (r = .378), and explanation (high)(r = .412). Initiate inquiry, cognitive conflict, and nonbuild-on were correlated with neither conceptual understanding nor epistemic view.

Regression analysis. Prediction of discourse moves on epistemic cognition

Hierarchical regression examined how the identified discourse moves predicted posttest epistemic cognition. We included only those independent variables that showed statistically significant correlation with posttest epistemic cognition. The order of entry was based on causal priority and relevance (Cohen & Cohen, 1983). We first entered prior epistemic cognition, followed by problem-centred uptake (high), explanation (high), and sustain inquiry (high)(see Table 9). Prior epistemic cognition scores were most important. Problem-centred uptake moves were entered before theory-building moves because they are of a higher order. The extent to which students problematized and worked on coherence reflected the general epistemic goal and orientation towards collective inquiry, and theory-building moves reflected inquiry and explanation processes and strategies.

Prior epistemic cognition explained 8.7% of the variance (R^2 = .087, p = .036). Adding high-level problem centred uptake explained an additional 7.5% with significance (R^2 = .162, p = .044). Adding explanation (high) and sustain inquiry (high) moves did not significantly contribute to prediction. This showed that the students' high-level problem-centred uptake discourse moves contributed to their posttest epistemic understanding beyond pretest scores. It suggests that the better students uptake the previous ideas and problem under discussion, the more likely they will develop better epistemic understanding about the theory-building nature of science.

4.4 | Research Question 3: Prediction of discourse moves on conceptual understanding

Hierarchical regression analyses were conducted to examine how the identified discourse moves and other variables predicted posttest conceptual understanding. Only the variables that were statistically significantly correlated with conceptual understanding were included.

TABLE 8 Correlations among Knowledge Forum discourse moves, epistemic cognition, and conceptual understanding

	1	2	3	4	5	6	7	8	9	10	11
1. Post conceptual											
2. Post epistemic	.489**										
3. Problem-centred uptake (low)	.141	.117									
4. Problem-centred uptake (high)	.378**	.339*	.532**								
5. Initiate (low)	.108	.1	.193	.018							
6. Initiate (high)	.076	.022	.236	.302*	.018						
7. Sustain (low)	.109	.202	.553**	.553**	.119	.015					
8. Sustain (high)	.172	.286*	.454**	.814**	−.017	.380**	.494**				
9. Explanation (low)	.12	−.008	.821**	.411**	.225	.03	.352*	.167			
10. Explanation (high)	.412**	.292*	.551**	.822**	−.086	.317*	.21	.540**	.471**		
11. Cognitive conflict	.218	.175	.499**	.415**	.214	−.03	.651**	.251	.352*	.19	
12. Nonbuild-on	−.241	−.091	.421**	−.035	.256	.049	.199	.116	.247	−.043	−.043

*$p < .05$.

**$p < .01$.

TABLE 9 Hierarchical regression on post-epistemic cognition in science

	R	R^2	R^2 change	F change
Prior epistemic	.295	.087	.087	4.67*
Problem-centred uptake (high)	.403	.162	.075	4.30*
Explanation (high) and sustain (high)	.414	.171	.009	0.255

*$p < .05$.

For order of entry, we followed causality-relevance and chronological sequence. Prior science understanding (including both pretest and achievement scores) is key to determining posttest conceptual understanding and so was entered first. After prior science understanding, KF discourse moves were entered as they took place during instruction that preceded posttest epistemic cognition (see Table 10).

Prior science understanding explained 21.3% of variance (R^2 = .213, p = .004). Adding high-level problem-centred uptake explained no significant additional variance. Adding explanation (high) explained an additional 6.7% of variance (R^2 = .323, p = .04). When post epistemic cognition was added, 5.4% of variance was added, but it was not significant (R^2 = .378, p = .056). These results suggest that, over and above prior science understanding, high-level explanation discourse moves contributed to students' conceptual understanding. It indicates that the more students contributed to the collaborative discourse through elaborated explanations, the more likely they scored higher on conceptual understanding.

TABLE 10 Hierarchical regression on post-conceptual understanding

	R	R^2	R^2 Change	F Change
Prior science knowledge	.461	.213	.213	6.356**
Problem-centred uptake (high)	.506	.256	.044	2.698
Explanation (high)	.569	.323	.067	4.457*
Post epistemic	.615	.378	.054	3.835

**p <. 01.

*$p < .05$.

5 | DISCUSSION

This study characterized elementary students' KF discourse moves from an epistemic and theory-building perspective. We identified two major kinds of discourse moves (problem-centred uptake and theory-building moves) and found significant differences regarding their occurrence in discourse threads depicting different levels of collective knowledge advancement. We also examined the relationship between discourse moves and epistemic and conceptual understanding at individual level and found that the identified discourse moves predicted epistemic and conceptual understanding.

5.1 | Characterization of discourse moves

Discourse analyses were conducted to examine the epistemic aspects of collaborative knowledge-building discourse. We first analysed KF discourse threads depicting different levels of knowledge building and advancement: fragmented discussion, knowledge sharing, knowledge construction, and knowledge creation (van Aalst, 2009). We then analysed the discourse moves within inquiry threads and identified two major kinds of discourse moves, that is, problem-centred uptake and theory-building moves. Problem-centred uptake moves were coded based on the notes' relation to previous notes and the problem under discussion, whereas theory-building moves were coded based on their different roles in the thread. The patterns overlap somewhat but are distinctive, as the former reflects students' epistemic goals of problematizing knowledge and coherently addressing the problem for community progress, and the latter reflects the epistemic processes of theory building and scientific inquiry.

Argumentation and theory building are important science practices. Many previous studies have examined online discourse from an argumentation perspective (Chiu, 2008; Felton & Kuhn, 2001; Lu et al., 2011; Nussbaum, 2008; Weinberger & Fischer, 2006), whereas few have conceptualized collaborative discourse as a theory-building process. We based our work on knowledge-building theories (Scardamalia & Bereiter, 2006) that emphasize continual idea improvement and theory building and explored ways of analysing collaborative discourse from a theory-building and epistemic perspective (Bereiter, 2012). Although different CSCL and knowledge-building studies have used questions and explanations to examine discourse (Hakkarainen, 2003; Lee et al., 2006), this study examined them as a system of theory-building processes, including initiating inquiry, asking questions, giving explanations, posing conflict, and sustaining inquiry. The analysis reflected the epistemic features of knowledge building (e.g., progressive explanation and sustained inquiry) and allowed us to understand students' epistemic inquiry in more connected ways.

This approach extends previous studies on the epistemic nature of individual notes (e.g., question and explanation; Hakkarainen & Sintonen, 2002) by emphasizing the connection among notes and ideas and enriches the literature on approaches to examining interaction in CSCL (Puntambekar, Erkens, & Hmelo-Silver, 2011). Rather than just coding and counting discourse moves (Lee et al., 2006) or qualitatively examining inquiry threads (Zhang et al., 2007), we adopted a code-and-count approach, while also considering the interactive and situated nature of discourse, using physical-level analysis and tracing the development of ideas. Such an approach has implications for analysing online discourse, as it both captures the interaction of ideas and allows for examining the relationship between identified discourse moves and other measures.

5.2 | Relations between discourse moves and collective knowledge advancement

Current CSCL and KB research focuses on collective knowledge advancement; and our analysis included both collective and individual aspects. Specifically, we examined whether and in what ways the identified discourse moves are associated with more or less collective knowledge advancement. The results showed that the high-level discourse threads (more knowledge advancement) had a higher proportion of high-level problem-centred uptake and theory-building moves. In these instances, ideas were more coherently built upon each other to address the inquiry problem; there were also more high-level explanations theorizing mechanisms and more emerging questions to sustain the inquiry. The results also showed that high-level discourse threads did not differ from low-level discourse threads in terms of cognitive conflict, low-level explanations, or nonbuild-on, indicating that merely expressing different ideas in online discussion (conflict) did not necessarily bring about knowledge advancement. Disagreement and conflict may provoke explanations and questions that need further tracking, while merely disagreeing and offering intuitive explanations were not sufficient and seldom led to knowledge construction and community knowledge advancement.

We also found that high- and low-level discourse threads did not differ in initiate inquiry (low) or initiate inquiry (high), indicating that, whether the inquiry thread was initiated as a fact-seeking question (low-level initiate inquiry) or an explanation-seeking one (high-level initiate inquiry), it did not affect inquiry thread quality. In group inquiry, it is usually not the individual's intention that determines the direction and depth of the inquiry but the group's shared cognition. It is argued here that we should not classify a given discourse pattern as fact-seeking or explanation-seeking, based merely on the questions asked (Hakkarainen, 2003); rather, we must examine how the community interprets and processes the question, and how its members uptake ideas for theory building. For example, a student may start a conversation by asking, "Can salt water conduct electricity?"—which is usually interpreted as a fact-seeking question. However, the question could contain tacit explanation-seeking overtones, depending on how the community processes it. After determining that salt water can conduct electricity, they could then also wonder why, and if it were the water that conducts electricity, the salt, or the combination thereof. With each response provided, the inquiry could deepen. However, if the community does not have an epistemic goal of problematizing collective knowledge, students are unlikely to be aware of these tacit meanings, nor the necessity for further explanation and therefore may only offer yes/no answers or simple factual responses. This finding indicates that, although encouraging students to initiate inquiry through good questions is important, it is even more important to scaffold the community to process the ideas in the questions and to deepen the inquiry.

5.3 | Prediction of discourse moves on epistemic and conceptual understanding

The analyses on the relationship between discourse moves and epistemic and conceptual understanding showed that students' engagement in high-level problem-centred uptake discourse move predicted their epistemic cognition over and above prior epistemic cognition. These findings support our hypothesis about the relationship between problematizing and coherence and epistemic cognition in science. Our results suggest that the more coherently students built on their peers' ideas to address the central problem in KF discourse, the more likely they were to understand science as a collective theory-building process.

The results also showed that high-level explanation/theorizing moves predicted conceptual understanding beyond prior science knowledge. This is consistent with the relationships between depth of explanation and conceptual understanding shown elsewhere (Lee et al., 2006). However, we did not find that post epistemic cognition further added to the explained variance, which is different from the previous studies (Mason, 2010; Stathopoulou & Vosniadou, 2007) that suggested the role of epistemic cognition in conceptual understanding. This is probably caused by the small sample size. The complex relationship among discourse moves, epistemic cognition, and conceptual understanding needs to be investigated further.

Some researchers have suggested possible influence of dialogic teaching in developing students' epistemic cognition (Bendixen, 2016). For example, Ryu and Sandoval's (2012) study shed light on the role of classroom argumentative discourse in developing students' understanding of the epistemic criteria for argumentation. Our study contributes and extends research on student dialogue by examining the role of online theory-building discourse in promoting students' epistemic understanding of the socially constructed nature of science.

This study also indicates that designing technology with epistemic implications is important for promoting students' epistemic understanding. The technological design of KF—that different ideas can be connected and built on for further improvement—has the epistemic implication that ideas are socially constructed and tentative. It also provides affordances to support students' epistemic practice, which impacts their epistemic understanding. As noted by Caswell and Bielaczyc (2002), KF could alter the relationship between students and scientific knowledge; as students engage in knowledge-building discourse, the epistemic implications of their knowledge-building practice may gradually help them understand the tentative nature of scientific knowledge and the progressive nature of scientific inquiry.

We also noted this study is limited, in that the sample size of the discourse threads is small, which limits the generalizability of the study's conclusions. Future research involving a larger sample size is needed to examine if consistent patterns can be observed. Additionally, the small sample size also limited our statistic approaches to examining the relationship among conceptual understanding, KF discourse moves, and epistemic cognition; future studies could test their interrelationships using larger samples in path analysis.

6 | CONCLUSION

This study contributes to our understanding of online discourse from epistemic inquiry and theory-building perspectives. Many studies in CSCL are concerned with socio-cognitive dynamics; this study continues this tradition and enriches the literature on epistemic aspects of online discourse. We developed a coding scheme to characterize students' online discourse moves on KF and showed how the identified discourse moves contributed to collective knowledge advancement. We found that problem-centred uptake, theorizing, and sustaining inquiry are important discourse moves that differentiate high- and low-level discourse and that cognitive conflict, initiate inquiry, and low-level explanations are not. This indicates that merely encouraging students to express different ideas and ask good questions to initiate inquiry is not enough to promote productive discourse; we must also scaffold students to work as a community to problematize inquiry, build coherently on others' ideas, make constructive use of new information for explanation and theorizing, and ask deepening questions to sustain the inquiry.

This study also contributes to our understanding of the relationship between knowledge-building discourse moves and epistemic cognition, which has rarely been studied. It shows that problematizing and building coherently on others' ideas to pursue problems predicted how students understood science as a collective theory-building process. It has implications for the ways in which collaborative discourse can be used to improve students' epistemologies of science and suggests the role of technology in facilitating this process.

ORCID

Feng Lin http://orcid.org/0000-0002-5059-4893

REFERENCES

Bendixen, L. D. (2016). Teaching for epistemic change in elementary classrooms. In J. A. Greene, W. A. Sandoval, & I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 281–299). New York: Routledge.

Bereiter, C. (1994). Implications of postmodernism for science, or, science as progressive discourse. *Educational Psychologist*, *29*(1), 3–12.

Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, N.J.: L. Erlbaum Associates.

Bereiter, C. (2012). Theory building and education for understanding. In M. A. Peters, P. Ghiraldelli, B. Žarnić, & A. Gibbons (Eds.), *The encyclopaedia of educational philosophy and theory*. Retrieved 6 November, 2013 from http://eepat.net/doku.php?id=theory_building_and_education_for_understanding.

Bereiter, C. (2016). The epistemology of science and the epistemology of science teaching. Paper presented at the 12th International Conference of the Learning Sciences, singapore.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education*, *11*(5), 514–529.

Caswell, B., & Bielaczyc, K. (2002). Knowledge Forum: Altering the relationship between students and scientific knowledge. *Education, Communication & Information*, *1*(3), 281–305.

Chan, C. K. K. (2001). Peer collaboration and discourse patterns in learning from incompativle information. *Instructional Science*, *29*, 443–479.

Chen, B. (2017). Fostering scientific understanding and epistemic beliefs through judgments of promisingness. *Educational Technology Research and Development*, *65*(2), 255–277.

Chen, B., Scardamalia, M., & Bereiter, C. (2015). Advancing knowledge-building discourse through judgments of promising ideas. *International Journal of Computer-Supported Collaborative Learning*, *10*(4), 345–366.

Chinn, C. A., Buckland, L. A., & Samarapungavan, A. L. A. (2011). Expanding the dimensions of epistemic cognition: Arguments from philosophy and psychology. *Educational Psychologist*, *46*(3), 141–167.

Chiu, M. M. (2008). Effects of argumentation on group micro-creativity: Statistical discourse analyses of algebra students' collaborative problem solving. *Contemporary Educational Psychology*, *33*(3), 382–402.

Chuy, M., Scardamalia, M., Bereiter, C., Prinsen, F., Resendes, M., Messina, R., … Chow, T. C. Y. (2010). Understanding the nature of science and scientific progress: A theory-building approach. *Canadian Journal of Learning and Technology*, *36*(1).

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Conley, A. M., Pintrich, P. R., Vekiri, L., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology*, *29*(2), 186–204.

Elby, A., Macrander, C., & Hammer, D. (2016). Epistemic cognition in cience. In J. A. Greene, W. A. Sandoval, & I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 113–127). New York: Routledge.

Elder, A. D. (2002). Characterizing fifth grade students' epistemological veliefs in science. In B. K. Hofer, & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 347–363). Mahwah, N.J.: London Lawrence Erlbaum.

Felton, M., & Kuhn, D. (2001). The development of argumentive discourse skill. *Discourse Processes*, *32*(2–3), 135–153.

Fischer, F., & Mandl, H. (2005). Knowledge convergence in computer-supported collaborative learning: The role of external representation tools. *Journal of the Learning Sciences*, *14*(3), 405–441.

Fu, E. L. F. (2014). Characterizing the discourse patterns of collaborative knowledge building. (PhD), The University of Hong Kong.

Fu, E. L. F., van Aalst, J., & Chan, C. K. K. (2016). Toward a classification of discourse patterns in asynchronous online discussions. *International Journal of Computer-Supported Collaborative Learning*, *11*(4), 441–478.

Golanics, J. D., & Nussbaum, E. M. (2007). Enhancing online collaborative argumentation through question elaboration and goal instructions. *Journal of Computer Assisted Learning*, *24*(3), 167–180.

Greene, J. A., Sandoval, W. A., & Bråten, I. (Eds.) (2016). *Handbook of epistemic cognition*. Routledge.

Gunawardena, C. N., Low, C. A., & Anderson, T. (1997). Analysis of global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *Journal of Educational Computing Research*, *17*(4), 397–431.

Hakkarainen, K. (2003). Progressive inquiry in a computer-supported biology class. *Journal of Research in Science Teaching*, *40*, 1072–1088.

Hakkarainen, K., & Sintonen, M. (2002). The interrogative model of inquiry and computer-supported collaborative learning. *Science & Education*, *11*(1), 25–43.

Hewitt, J. (2001). Beyond threaded discourse. *International Journal of Educational Telecommunications*, *7*(3), 207–221.

Hmelo-Silver, C. E., & Bromme, R. (2007). Coding discussions and discussing coding: Research on collaborative learning in computer-supported environments. *Learning and Instruction*, *17*(4), 460–464.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, *67*(1), 88–140.

Hong, H.-Y., Chen, B., & Chai, C. S. (2016). Exploring the development of college students' epistemic views during their knowledge building activities. *Computers & Education*, *98*, 1–13.

Hong, H.-Y., & Lin, S.-P. (2010). Teacher-education students' epistemological belief change through collaborative knowledge building. *The Asia-Pacific Education Researcher*, *19*(1), 99–110.

Hong, H. Y., Scardamalia, M., Messina, R., & Teo, C. L. (2015). Fostering sustained idea improvement with principle-based knowledge building analytic tools. *Computers & Education*, *89*, 91–102.

Knight, S., & Mercer, N. (2017). Collaborative epistemic discourse in classroom information seeking tasks. *Technology, Pedagogy and Education*, *26*(1), 33–50.

Lai, M., & Law, N. (2006). Peer scaffolding of knowledge building through collaborative groups with differential learning experiences. *Journal of Educational Computing Research*, *35*(2), 123–144.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497–521.

Lee, E. Y. C., Chan, C. K. K., & Aalst, J. (2006). Students assessing their own collaborative knowledge building. *International Journal of Computer-Supported Collaborative Learning*, *1*(1), 57–87.

Lin, F., & Chan, C. K. K. (2018). Promoting elementary students' epistemology of science through computer-supported knowledge-building discourse and epistemic reflection. *International Journal of Science Education*, 1–20. https://doi.org/10.1080/09500693.2018.1435923

Lipponen, L. (2000). Towards knowledge building: From facts to explanations in primary students' computer mediated discourse. *Learning Environments Research*, *3*(2), 179–199.

Lu, J., Chiu, M. M., & Law, N. W. (2011). Collaborative argumentation and justifications: A statistical discourse analysis of online discussions. *Computers in Human Behavior*, *27*(2), 946–955.

Mason, L. (2010). Beliefs about knowledge and revision of knoweldge: On the importantce of epistemic beliefs for intentional concpetual change in elementary and middle school students. In L. D. Bendixen, & F. C. Feucht (Eds.), *Personal epistemology in the classroom theory, research, and implications for practice* (pp. 258–291). Cambridge, UK: New York: Cambridge University Press.

Nussbaum, E. M. (2008). Collaborative discourse, argumentation, and learning: Preface and literature review. *Contemporary Educational Psychology*, *33*(3), 345–359.

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge building discourse explorer: A social network analysis application for knowledge building discourse. *Etr&D-Educational Technology Research and Development*, *60*(5), 903–921.

Puntambekar, S., Erkens, G., & Hmelo-Silver, C. (Eds.) (2011). *Analyzing interactions in CSCL: Methods, approaches and issues*. Springer Science & Business Media.

Resendes, M., Scardamalia, M., Bereiter, C., Chen, B., & Halewood, C. (2015). Group-level formative feedback and metadiscourse. *International Journal of Computer-Supported Collaborative Learning*, *10*(3), 309–336.

Rosenberg, S., Hammer, D., & Phelan, J. (2006). Multiple epistemological coherences in an eighth-grade discussion of the rock cycle. *Journal of the Learning Sciences*, *15*(2), 261–292.

Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education*, *96*(3), 488–526.

Scardamalia, M. (2004). *CSILE/Knowledge forum education and technology: An encyclopedia*. (pp. 183–192). Santa Barbara: ABC-CLIO.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97–118). New York: Cambridge University Press.

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 397–417).

Scherr, R. E., & Hammer, D. (2009). Student behavior and epistemological framing: Examples from collaborative active-learning activities in physics. *Cognition and Instruction*, *27*(2), 147–174.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, *82*(3), 498–504.

Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction*, *18*(3), 349–422.

Stathopoulou, C., & Vosniadou, S. (2007). Exploring the relationship between physics-related epistemological beliefs and physics understanding. *Contemporary Educational Psychology*, *32*(3), 255–281.

Suthers, D., Dwyer, N., Medina, R., & Vatrapu, R. (2007). A framwork for electic analysis of collaborative interaction. Paper presented at the The Computer Supported Collaborative Learning, New Brunswick.

Tsai, C. C. (1999). The progression toward constructivist epistemological views of science: A case study of the STS instruction of Taiwanese high school female students. *International Journal of Science Education*, *21*(11), 1201–1222.

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning*, *4*(3), 259–287.

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education*, *46*(1), 71–95.

Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of 9- and 10-year-olds. *Educational Technology Research and Development*, *55*(2), 117–145.

How to cite this article: Lin F, Chan CKK. Examining the role of computer-supported knowledge-building discourse in epistemic and conceptual understanding. *J Comput Assist Learn*. 2018;34:567–579. https://doi.org/10.1111/jcal.12261