Fostering Students' Epistemic Beliefs and Scientific Understanding through Knowledge Building

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Abstract This study implemented a computer-supported knowledge building environment in a science class using reflective assessment in fostering epistemic belief changes and scientific understanding. The participants were a group of Year 7 students from a Hong Kong international school. Data sources included the Epistemic Beliefs Questionnaire (EBQ) to examine students' beliefs on the nature of science and scientific knowledge, domain tests, students' participation on Knowledge Form analyzed by Analytic Toolkit and portfolios. Knowledge building portfolios and reflections were adopted in this study, both to scaffold and to examine epistemic beliefs and dynamics the knowledge building process. Results indicated that knowledge building intervention and Knowledge Forum have positive effects on fostering conceptual understanding in science learning and promoting changes in students' epistemic beliefs. Student portfolios and teacher interviews were analyzed to illuminate how knowledge building might support epistemic growth. Implications for knowledge building designs in examining and fostering epistemic growth are discussed.

Keywords: Scientific understanding, knowledge building, epistemic belief, reflective portfolio.

Introduction

Considerable research has accumulated showing the role of knowledge building and Knowledge Forum in scaffolding students' scientific understanding and inquiry and idea development (Caswell & Bielaczyc, 2002; Hakkarainen, 2004; Kangas, Seitamaa-Hakkarainen, & Hakkarainen, 2007; Oshima et al., 2006; Zhang et al., 2007; 2011). More recently, research into knowledge building inquiry has also shown its role in facilitating students' epistemic belief development (Lam, 2012; Lin, 2015). How students think about knowing and knowledge has been shown to be importantly related to learning and cognition (Pintrich & Hofer, 2001). If students think knowledge is fixed, there would be no need for them to construct knowledge and to engage in inquiry; and if they believe that knowledge comes only from authoritative source, they would not have agency in their learning. Knowledge building is not only pedagogy but an epistemological theory postulating how knowledge can be advanced through collective efforts (Bereiter, 2002). Students work together as communities of scientists advancing the frontiers of their knowledge (Scardamalia & Bereiter, 2006). Developing knowledge building environments would provide epistemic-rich environments for examining and facilitating students' understanding of nature and knowing and knowledge. While there is increased research interest, how knowledge building can work in regular classrooms and whether beginning knowledge-building teachers can also help develop knowledge building and epistemic change has been less examined.

Previous researches have examined the role of reflective assessment with students' reflection on the progress of knowledge building in fostering both individual and collective knowledge advance. (Lee et al., 2006; van Aalst & Chan, (2007) This study continued this line of previous study and sought to develop a knowledge-building environment to both scaffold and to assess students' epistemic reflection and domain understanding. The research sought to examine further epistemic beliefs development using student-directed assessment and explored teacher's and students' views of how epistemic beliefs might develop in the classroom. Specifically, the following research objectives are included: 1) To examine if there are differences in students' domain understanding and epistemic beliefs after the knowledge building intervention with reflective assessment. 2) To examine the relation among KF participation, domain understanding and epistemic beliefs. 3) To examine how knowledge building intervention and reflective assessment may have effect on changes of students' epistemic beliefs?

Methods

Participants

Participants of this study were a group of eighteen Year 7 students from an international school in Hong Kong They experienced a collaborative knowledge building inquiry for five weeks in the 2014-2015 academic year. The participants were all computer literate and could use their iPad and school-provided MacBook to assess the Internet in class; however, they had no prior experience using Knowledge Forum (KF).

Design

A CSCL knowledge building environment mediated by Knowledge Forum was designed and implemented in a science class using reflective portfolio and knowledge building reflection in fostering students' scientific understanding. Knowledge-building pedagogy and

Knowledge Forum were implemented and integrated with the science curriculum as a new way of learning during classroom sessions over a five-week period from May to June 2015. There are 4 sessions every week and each takes 60 minutes. The curricular topic involved was Energy and Sustainable Living. The teacher who participated in this project had over 10 yearslved was Energy and Sustainable Living. Regarding the pedagogy, the class involved students generating questions, researching information, engaging in the online discussion, building on each other's theories and reconstruct their ideas collectively. The instructional design consisted of four phases, which are described in detail, below.

Phase 1: Developing a Collaborative Classroom Culture. We first cultivated a collaborative classroom learning culture in which students feel safe to express their ideas and gain more cognitive responsibilities for the whole class. A number of collaborative learning activities were designed to foster the concept of a learning community. In this stage, students experienced collaborative learning through a series of activities like Think Pair and Share, Knowledge building wall, Group Concept Mapping presentation and Jigsaw learning etc. They began to build a sense of generating their own questions and searching authoritative sources to answer the questions.

Figure 1. Knowledge building wall and example of students' concept map.

Phase 2: Knowledge Building inquiry on Knowledge Forum. Knowledge Forum 4.7 (web vision) was introduced to and implemented in the class after students became familiar with the collaborative learning environment. Students were given a Knowledge Forum user guide that included a general introduction to its functions and scaffoldings (e.g. My theory, New information) and showed them how to post, read and build on notes. The students were then introduced to the view and given hands-on training on how to use Knowledge Forum. Students were asked to post notes on the Energy view related to key questions arising from the post-discussion knowledge building wall (e.g. energy and energy use, global warming, etc.). They could also include some authorized information to help articulate their ideas and to answer questions on Knowledge Forum (video clips, textbooks, government reports, etc.)The class instructional design was aligned with Knowledge Forum notes to enhance student learning, and sharing new information on Knowledge Forum promoted students' further exploration of some areas. In general, new topics spring from student questions, generate new questions that drive students to learn about the topic; the diverse ideas generated by student efforts to answer those questions direct the whole discussion to go further.

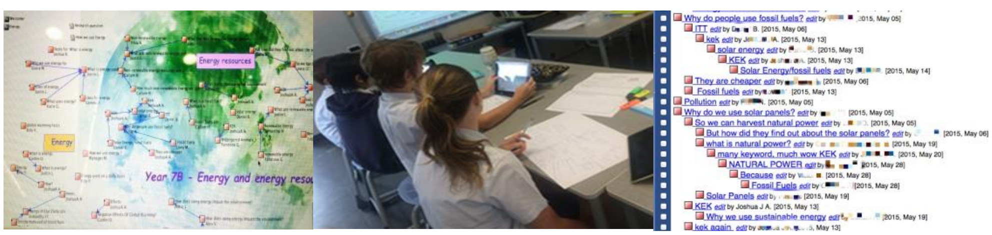

Figure2. Knowledge Forum database.

Phase 3: Deepening Knowledge Building Discourse. After students posted some notes in Knowledge Forum and developed some clusters. A reflective knowledge building talk was designed in the subsequent class session for students to share their ideas on what constitutes good notes/discussion and how to develop better discussions on Knowledge Forum. Following the KB talk, they were introduced to characteristics of a good note and to four knowledge building principles to scaffold their knowledge building inquiry and discussions on Knowledge Forum; they were also given and asked to comment on several cluster of notes, based on the principles and criteria of good notes. After the KB talk, students began a new cycle of group work, had a more purposeful discussion on Knowledge Forum, designed their own research questions within the group, researched resources and finally each group came up an artifact that demonstrated their learning and understanding of a specific topic.

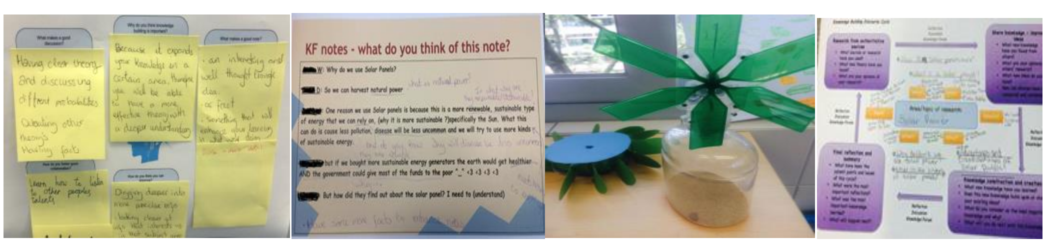

Figure3. Knowledge building reflection and students group work.

Phase 4: Knowledge Building Assessment. Apart from typical quantitative knowledge building measures, participants in this study were also asked to write reflective essays and portfolio notes about their personal and collective advances. Knowledge building reflection was implemented to both scaffold and assesses students' scientific understanding and epistemic development and knowledge-building inquiry.

Data Sources and Analysis

A written pre-/post-test domain test, consisting of four open-ended questions addressing key concepts, was conducted to assess students' level of understanding of the Energy and Sustainable Living unit. Students' responses were coded using a four-level scale (developed by the researcher and the teacher) that illustrates different levels understanding. All students' pre-/post-test responses were coded by the researcher and an independent rater scored 40% of the domain test. Inter-rater reliability was .892 (pre-test) and .982 (post-test), based on Pearson's Correlation.

A pre-/post-test self-report Epistemic Beliefs Questionnaire (EBQ) was administered to examine students' beliefs on the nature of science and scientific knowledge before and after the intervention (see Appendix 1). The version used in this study was Lam's（2012）revised 28-item Epistemic Beliefs Questionnaire, which modified the earlier work of Conley and colleagues (2004) by extending it to 28 items to reflect four dimensions of epistemology about the nature of knowledge (certainty and development of knowledge) and knowing in science (source and justification). *Source* concerns beliefs about knowledge residing in external authority (e.g., one must believe most things one reads in science textbooks) (Lam, C, K, 2012). *Certainty* refers to beliefs regarding correct answers (e.g., scientists always agree about what is true in science). *Development* indicates beliefs about the development of science as a changing subject (e.g., scientific knowledge will not change over time). *Justification* refers to how individuals use and justify knowledge in science (e.g., ideas in science can come from one's own questions).The meaning of each item was explained to the students in this project to avoid possible misunderstandings. Students' responses to the questionnaire were analyzed and marked by the researcher. Each item was rated on a five-point Likert scale (i.e. 1 =strongly disagree, 5 = strongly agree). Items reflecting source and certainty scales were reversed, so that higher scores indicated more sophisticated beliefs.

Analytic Toolkit (ATK) was used to retrieve and analyze students' activities on Knowledge Forum using log data, as in other knowledge-building research (e.g., Lee, Chan & van Aalst, 2006; Zhang et al., 2009). Students' writing on Knowledge Forum was analyzed for questions and explanation. The depth of individual notes was also analyzed to identify their quality and the different levels of knowledge building inquiry they revealed. The questions in the database were coded by the notes' author and depth of the explanation revised according to a four-level scheme derived from Y.C. Lee's (2009) original rating scheme. Knowledge building portfolio was also coded. The rating scheme of the portfolio notes was revised to a four-point scale based on Y.C. Lee's (2009) original six-point rating scheme.

Students' focus group interviews and the teacher interview were conducted at the end of instructional design, immediately after the post-test. The interview was to examine their experience with knowledge building and transcripts were analyzed. The interviews provided qualitative data on students' views on how knowledge building and Knowledge Forum affected their academic performance and their views of science learning.

Results and Findings

Knowledge Building Database Analysis

Students' participation on Knowledge Forum was measured using the Analytic Toolkit (ATK), which provided an overview of their contributions to the database and their discussions on Knowledge Forum. The ATK general descriptive picture revealed that, over a five-week period from May to early June, the 18 student participants contributed 237 written notes. Table 1 shows student's' overall participation and interactions, and their high level of contributions on Knowledge Forum. On average, each student created 12 notes, read 44.2% percent of other students' notes and used 10.8 scaffolds; In addition, there were frequent student interactions on Knowledge Forum, with links being made to 55.6% of all notes posted.

Table 1.
Descriptive measures for knowledge building activities on Knowledge Forum ATK Index.

ATK Index	Mean	Standard deviation
Number of notes created	12.0	7.26
Percentage of notes read	44.2%	22.65%
Number of notes revisions	1.8	1.67
Number of scaffolds	10.8	8.6
Percentage of notes linked	55.6%	18.2
Percentage of notes with keywords	24.9%	17.79%

An overview of the database revealed a high rate of participation on Knowledge Forum. A detailed analysis of the number of questions and explanations posted over time was also conducted. Figure 4 shows that students generally focused on generating questions in the first week, but began to post more explanations to answer those questions and to advance the discussion in the following weeks.

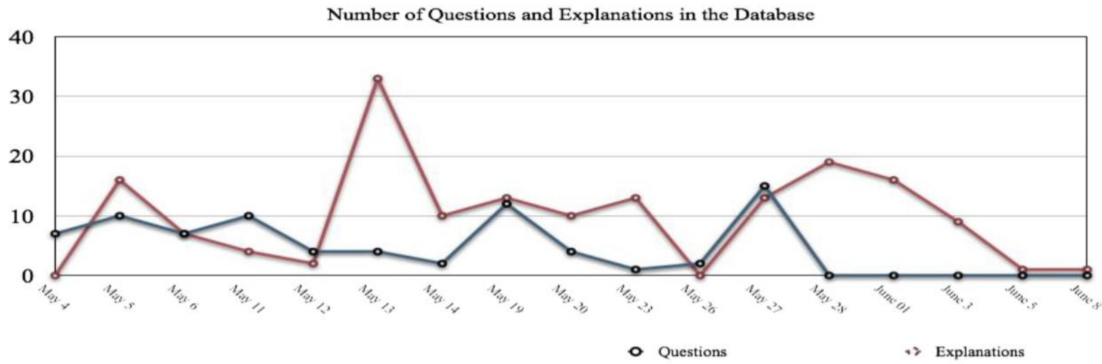

Figure 4. Number of questions and explanations on Knowledge Forum over time.

Qualitative analyses were undertaken to characterize knowledge building, so as to better understand students' activities on Knowledge Forum and explore how they worked collaboratively using it. To identify the quality of the questions and explanations and examine any differences there over time, all the questions and explanations in the database were coded according to a four-level scheme derived from Y.C. Lee's (2009) original rating scheme. A second rater independently scored 40% of the notes. Inter-rater reliability was .816, based on Pearson's Correlation.

There were more explanations (146) than questions (89) in the database. The level of the questions generated in the whole period was quite high, with roughly 60% being Level 3 or Level 4 questions; in comparison, the depth of explanation was lower, with only 30% of explanations being high level over the whole period. However, significant changes were found in depth of explanation; the percentage of Level 1 explanations dropped dramatically over the two periods (from 37.10% to 13.23%), while Level 3 and 4 explanations increased over time. The results suggest that students wrote more high-level explanations over time.

Table 2.
Percentages of high and low level inquiry and explanations in different periods.

	Depth of Inquiry			**Depth of Explanation**		
	P1	**P2**	**Whole Period**	**P1**	**P2**	**Whole Period**
Level 1	18.18%	8.80%	13.48%	37.10%	13.23%	26.00%
Level 2	15.90%	31.11%	23.59%	42.30%	48.53%	45.20%
Level 3	61.36%	55.55%	58.42%	20.50%	33.83%	26.71%
Level 4	4.50%	4.40%	4.40%	0%	4.40%	2.00%
Notes	44	45	89	78	68	146

Knowledge Building Discourses

Qualitative analyses were undertaken to characterize knowledge building, so as to understand better students' activities on Knowledge Forum and explore how they worked collaboratively using it. The Inquiry threads analysis was taken from the database to demonstrate the development of the knowledge building community, the diverse ideas within the community, interactions within it and the process of the rise-above and idea – development. The following episode shows how students deepened their understanding of energy resources by a series of problem-solving questions and explanations.

Note 1 Question generation	*What is a fossil fuel? By S9. [2015, May 05]*
Note 2 Explanation	*Fossil fuels are... by S2. [2015, May 06]* *My Theory Fossil fuels are resources that are burnt to make electricity and to make things (such as cars) move. These fossil fuels normally consist of coal, oil and fuels.*

Note 3 Explanation	*Fossil fuels by S13 2015, May 13]* *New information The United States gets 84% of its total energy from oil, coal, and natural gas, all of which are fossil fuels. Fossil fuels are used to fuel cars and airplanes, power electricity plants, and heat our homes. They are also used to make medicines, cosmetics, plastics, synthetic fabrics, and lubricants. When you brushed your teeth today, you used a product made from oil – toothpaste. Look at your shoes – they are a product made from oil. Sunglasses, tires, tennis balls and TV's are all products of oil and gas.*

This thread started with S9nd gas.Sunglasses, tires, tennl fuel; S2 answered the question in his own words, first expressing his understanding of fossil fuels and then illustrating that understanding with examples. S13 responded with authoritative information and offered more detail on fossil fuel usage; the Note's examples made the theories more relevant to daily life and facilitated understanding.

Note 4 Question generation	*Energy in Our Daily Life by S17[2015, May 05]* *My Theory I think we need to reduce the amount of energy used in our daily life. I need to understand How much energy is used daily by the WORLD daily?*

S17 came up with the idea of reducing energy use in life and then raised a new question about another aspect of energy resources, which led the discussion to a deeper level and explored matters further as a result.

Note 5 Question generation	*Hmm.. by S9[2015, May 06]* *Why would we have to limit our use of energy, what does it do? This theory cannot explain Also, they use oil the most in our world. New information*
Note 6 Explanation	Energy used on a daily basis by S2[2015, May 13] On a daily basis a country like America uses 5% of the hemisphere energy, whereas a country of high poverty will use about eight %.

The information in Note 4 made the students aware of the problems that may occur; and S9 then conservatively used the information to question the idea of limiting the use of energy. After that, they moved to the discussion toward the effects of energy use, and promoted further exploration on why energy use should be reduced. Note 6 was another response to Note 4, and provided information on the use of energy resources.

Note 7 Questionnaire generation	*Fossil fuels by S4[2015, May 13]* *I need to understand What happens if start to use more Fossil fuels?*

S4 considered the possible problems using information from the previous Notes and generated a further question that led the community to think about what could happen if people were to use more fossil fuels. The inquiry asked open-ended questions and collected diverse ideas on the problem.

Note 8 Explanation	*KEK by S9[2015, May 13]* *My Theory if we use more fossil fuel then the pollution will get drastically increased and more disease will occur, such as asthma. So we use sustainable energy to reduce the amount of pollution and disease. Putting our knowledge together*
Note 9 Explanation	*Re: Fossil fuels by S3. [2015, May 13]* *My Theory We'll eventually turn our world into a ball of water or we won't be able to breath or we will just run out of them.*
Note 10 Questionnaire generation	*kek by S9. [2015, May 13]* *How can we prevent this - and how can we stop it?* *Are there any ways, or are we screwed!?*

In Notes 8-10, S9 provided and explained his opinion on the consequences of excessive energy use and then asked what could be done to prevent catastrophe; this is very important, as it shows that the student had identified problems and were seeking solutions collectively.

Note 11 Explanation	*Fossil Fuels: Damaging the Environment by S11. [2015, May 13] We could stop fossil fuels from damaging the environment by alternating between alternate energy, like solar panels. We should leave 75% of fossil fuels underground to avoid the worst of climate change.*
Note 12 Explanation	*KEK by S11. [2015, May 13]* *Good theory, I think that we should a leave 75%-90% of the fossil fuels underground too, so we can avoid climate change, disease etc. So if we use these kinds of things then we can be more sustainable. Putting our knowledge together*
Note 13	*Solar energy by S4. [2015, May 13] We could use solar energy*
Note 14 Explanation	*Solar Energy/fossil fuels by S5. [2015, May 14]* *We could convince the government to stop using fossil fuels and put up solar panels by giving them a letter about the things that will happen if we keep using fossil fuels e.g. many animals can come extinct.*

Note 11 to Note 13 showed different possible solutions uels and put up solar panels by giving them a letter about the things that will happen if we keep using fossil fuels e.g. many animals can come not arguing which of the diverse ideas were better, but building on each othered different possible solutions uels and put up solar paneS11 and S13 mentioned using solar power to reduce pollution; S3 first accepted these ideas and then deepened collective understanding by involving the government, suggesting that the students could write a letter describing the negative effects of the problem and persuade the government to stop using fossil fuels and try solar panels instead. This response put together information from previous notes and provided evidence of students' individual and collective growth.

The cluster of notes began with a simple request for factual information, but as the students generated their own questions, being expose to diverse ideas, searching authoritative information for further explanation, their understanding of this topic were gradually deepened. This question-and-explanation mode made the cluster a gradual problem-solving process; the community worked together on a certain problem, collectively advanced community knowledge, elaborated on their ideas and eventually came up with good solutions.

Differences on Scientific Understanding and Epistemic Beliefs

Analysis using paired t-test on domain understanding shows a significant difference between pre-test scores (M =1.512, SD =.494) and post-test scores (M =2.308, SD = .669), t (17) = -6.265, p = .008. The results, although drawn from a single group with no comparison, provide some preliminary indications that knowledge building intervention and Knowledge Forum might have a positive effect on fostering domain understanding in science learning. This aligns with the finding that knowledge building environments promote deeper conceptual understanding and better learning outcomes. (Lee, 2013; Lee et al., 2006; Lam & Chan 2002, 2012).

Students' epistemic beliefs about science were measured using the Science Learning Questionnaire, and the responses analyzed in four dimensions (Certainty, Source, Development and Justification); overall epistemic belief scores were also examined. Statistical analysis shows no significant differences in any of the four dimensions; however, due to the small sample size, statistical effects are not the most appropriate. In the latter part, qualitative analyses will be employed to illustrate the possible role and dynamics of knowledge building.

Knowledge Building Participation, Domain Understanding and Epistemic Beliefs

Quantitative Findings

Analysis of correlations result shows that students notes linked in KF (ATK index) were significantly correlated with post-test epistemic beliefs (r = .488* , p< 0.05), suggesting that students who had more notes linked to in the database tended to have more sophisticated beliefs about science learning. Significant correlation was also obtained between studentse tended to have more sophisticated best epistemic beliefs (= .768* , p< 0.05), suggesting that students who engaged in more collaborative activities may be more likely to view science in more constructive ways; those who participated more on Knowledge Forum also wrote better questions and explanations.

Unexpectedly, no significant correlation was found between domain understanding and knowledge building measures; this may be because the small sample size (only 18 participants) made it difficult to research significance, or because the knowledge building activities had such a powerful effect on studentsing actietnderstanding that all students improved greatly in the post-test, without significant differences amongst them; there is some evidence of this in the students' interviews and knowledge building reflections.

We also employed contrastive groups to identify differences between high and low groups. The participants were divided into high knowledge building group and low knowledge building group based on their contributions on Knowledge Forum; each group had 9 students. Analysis of correlation results show that low KB group experienced significant changes in domain understanding (t = -4.305, p < 0.05), but no significant changes in epistemic beliefs. The high KB group showed significant changes in both domain understanding (t =-

4.379, $p< 0.05$) and epistemic beliefs ($t = -3.325$, $p< 0.05$). These results suggest that both groups of students (high and low KB group) changed significantly from pretest to posttest on their domain understanding in this KB environment. For epistemic beliefs, the findings suggest that the group of students who contributed more and engaged in more collaborative activities on KF (high KB group) changed more from initial, naïve beliefs to more sophisticated beliefs. There was however no change for the low-KB group who participated less on knowledge forum.

Table 3.

Comparisons between high and low KB groups.

Group	Dimensions	Pre-test		Post-test		T	sig
		Mean	SD	Mean	SD		
High KB Group	Domain Test	1.36	.31	2.23	.74	-4.379	.002
	EB Overall	14.59	1.27	15.60	1.57	-3.325	.013
Low KB Group	Domain Test	1.66	.61	2.39	.63	-4.305	.003
	EB Overall	16.08	.68	15.69	2.18	.550	.597

This finding is consistent with Hakkerrainen's (1999) research on students' improvements in depth of explanation, Hakkarinen's (2004) research examining shifts from fact-based to explanation-based inquiry, Chan's (2001) research on assessing and fostering collaborative knowledge building inquiry and discourse, and Lee's (2009) research on assessing and fostering collaborative knowledge building among Chinese high school students. In Chan's (2001) research, the author noted that simply asking questions was not enough; one must also engage in constructing explanations (e.g., ask explanation-based questions) to develop new understandings. In addition, generating questions and engaging in explanation in the context of scientific inquiry are also important knowledge building activities that trigger and guide explanation and theory construction (Chi, 2000; Okada & Simon, 1997). Continues research on knowledge building also shows that students who engaged more in KB also shows more changes in epistemic beliefs. (Lin,2015. Lam 2012)

Qualitative Findings

Quantitative results suggest preliminary evidence on role of knowledge building on students' epistemic beliefs and they would be elaborated further with qualitative findings based on portfolios，knowledge building reflection and interviews. In the following discussion, we present a selection of extracts from the qualitative data that demonstrates students' changes in the epistemic beliefs in four dimensions and illustrated how the changes in their epistemic beliefs might be related to knowledge forum participation and guiding knowledge building principles in designing this intervention.

Justification

It is encouraging to see that students portfolio shows links between knowledge building experience and development in the dimension of Justification (i.e., about how individuals use and justify knowledge in science.).Justification is usually considered just in terms of justifying one's own idea with evidence but in knowledge-building environment, students consider validity and usefulness of their ideas in relation to others' ideas; they are comparing their models in relation to other models. For example, students understood the various ideas proposed about a given problem, including those ideas that contrasted with their own.

> *"Having different thoughts and opinions can be really good when you are looking at a particular topic area. It can make you look at the problem differently, so you can solve it in a different way and have a broader understanding of it."* S11

These changes might be explained by the different experiences they had in the normal class and the knowledge class. Evidence could also be found in the students' interview about knowledge building class. For example, S16 noted that in the knowledge building class, *"we learn from each other, which is how other people's research can combine. We don't normally do that [in normal classes]. It is a different way for us; we can share our ideas in the class, but we can still share our ideas within the technology. It is a little different, but it is good in a way that is combining both."*

> *"It is good to find how our ideas are related to each other's ideas [than having] just one main idea or the teacher telling you all the right answers. We can express our opinions or share ourselves." S2*

> *Sometimes I would ask a question on global warming and answer it myself; some might be correct and some might be incorrect. If one of my classmates replied, they could tell me what I could improve on and what I could have done better and we could help each other and other people could read [our notes]; that would help more than one person and be useful as well. Having different opinions is important, because you can see how other people's opinions integrate and then you can see different viewpoints. (S14)*

The interview excerpts demonstrated how their ideas were justified and also gradually improved by their being exposed to different viewpoints on a topic, and by continuous questioning, building on and explanations. The idea improvement process on Knowledge Forum encouraged the students to consider how to deepen their understanding, which is essential to advancing discussion and collective learning. This is highly related to the underpinning knowledge building principles (Authentic problem, Idea diversity, Epistemic Agency) and demonstrated the effects of the principle guided intervention in promoting students epistemic development.

Source

The students' portfolio notes and knowledge building reflections also showed that they had more sophisticated beliefs on the dimension of sources (i.e., about knowledge being possessed by external authorities).Students engaged in the knowledge building environment relied less on authorized sources (teachers, textbooks); instead, they gathered information from multiple alternative sources (websites, newspapers, textbooks) and used it to make inferences and evaluate conflicting ideas.

> *I also did research on how electricity is created and I found out that the most renewable sources are solar panels and wind turbines (S13)*

> *I enjoyed doing research and sharing it through Knowledge Forum (S17)*

> *As for Knowledge Forum, one question started with – 'What is pollution?'. Many students began to find answers either with the information they knew or looked up online. (S11)*

As the extracts show, unlike normal classes, the knowledge building class showed students a new way of learning, in which students could either learn by themselves or by collaborating with their peers. The collaborative knowledge building process provided them with opportunities to use authoritative sources and other information sources, as data for their own problem sources and idea-improving processes， which turns to be a good demonstration of using knowledge building principles (Constructive Uses of Authoritative Sources) to scaffolding students to develop more sophisticated understanding about knowledge being possessed by external authorities.

Certainty

When articulating the collaborative efforts process, students doubted the certainty of knowledge (i.e., beliefs regarding correct answers.), making their own judgments and eliciting truth through a problem-solving inquiry. They question the quality of the resources at hand and the model answers provided, and discussed what they found in their own research with their peers. This impacted, to a degree, students' beliefs regarding right answers (Knowledge of certainty) and reflected awareness that they could construct and create new ideas by working collectively. Some even mentioned aspects of theory building when discussing how they worked with ideas:

> *Knowledge Forum enhances our learning by questioning our theories and ideas and helps us collaborate more with our peers as all of their ideas and theories may question us. (S5)*

> *It is good to find how our ideas are related to each other's ideas [rather than having] just one main idea or the teacher telling you all the right answers. We can express our opinions or share ourselves*." S2

The students' engagement in the knowledge building environment led them to stop holding fixed beliefs about science problems (finding the right/model answers), and instead focus on diverse or even conflicting ideas, and elaborate on them to improve their understanding of the problem.

Development

The students' reflections demonstrated that knowledge building inquiry and knowledge building principles (e.g., ideas diversity and idea development) also positively affected the development dimension – i.e., students' beliefs about the development of science as a changing subject.

> *I feel that people share their ideas out but **sometimes their ideas can be changed**. One example is that I had never thought global warming affected anything except the temperature of the earth and that changed the fact that ice is melting but after reading some notes, my ideas changed. (S17)*

> *I think it is a good way to share knowledge. Like, one person has a question and then someone can answer it and ask more questions. We can deepen our discussion by someone reply to the original question and then someone may ask for explanations. When you read more notes people have posted and you build on **then your ideas will gradually improve and change**. (S15)*

> *Without improving our ideas, science would have faded away, centuries ago and facts like the Earth being rounded not flat and Pluto being a dwarf planet would not exist. Overall, Knowledge Forum enhances our learning by questioning our theories and ideas and helps us collaborate more with our peers as all of their ideas and theories may question us. (S17, Interview)*

As the notes show, students identified that the knowledge building process started with simple questions, but could spark more questions and lead to deeper discussions. They then explained how their ideas changed and improved as they participated in the knowledge building activities as a community and transferred their experiences in the knowledge building class to help them understand the development of science. This may provide some evidence that introducing knowledge building principles (Raise above, Improvable ideas, Community knowledge) has positive effect on epistemic development in the dimension of development.

The employment of knowledge building portfolios and reflection was an attempt to assess epistemic beliefs and thinking processes in a computer-supported knowledge building context, in a more in-depth manner than that allowed by a self-reported questionnaire. Analysis of the results indicates that students' scientific knowledge was relevant to authentic problems, and that they appeared to adopt authoritative information as scientific evidence when making judgements in community discourses. The participants also developed a belief and practice in using complex sources to explain underlying theories in science. The portfolios and reflections demonstrate participants' cognitive understanding and conceptual advances, and indicate a shift from shallow to more sophisticated beliefs over time. This is consistent with pervious findings that knowledge building is effective in improving epistemic beliefs about science. (Lam & Chan, 2012; Lin, 2015)

In the teacher interview, the science teacher expressed his views on knowledge building inquiry and the impact of knowledge building activities and Knowledge Forum on students' learning and epistemic beliefs' development. In his opinion, the knowledge building environment enabled students to see diverse ideas and thus become more aware of the significance of conflict in science learning:

> *In terms of certainty, I think Knowledge Forum helped [students] to see diversity and that thing are not like the items in the questionnaire (Most questions in science have one right answer; You like working on science problems that have model answers), through which students realized that there is not always one good idea, not all the questions in science always have one right answer.*

The teacher also addressed student engagement in knowledge building and Knowledge Forum through which students used and justified scientific knowledge, justification is fostered in the context of the community. Students' participation on Knowledge Forum and the interactions amongst ideas were important to their beliefs about the development of science as a changing subject:

> *I think Knowledge Forum really supports the development of justification because in knowledge building inquiry [students] can generate their own questions, ideas. The important thing is they can look at a cluster of notes and see links between the notes so that they can synthesize their ideas, put their ideas together and form a more complex understanding of the problem.*
>
> *Sometimes scientists have conflicting ideas. Idea diversity will not only help them to learn about science but also to appreciate the morals, ethics, different ideas of science. These things are really important in science, because science is about creating things that improve our lives and improve society. Sometime science will support one group but conflict with another group. Science develops in this way.*

The teacher also mentioned how students developed their understandings of science problems on KF:

> *I think Knowledge Forum really supports this, because when we involve their ideas and their understanding, this may change their ideas. The idea of KF enables them to take something initially simple or fundamental to a more complex conceptual knowledge. For example, what is sound? They begin with some naive idea, like sound is …; they can use these isolated words or terms, then they need to build more complex understanding, like what is wave-like behavior? So I think Knowledge Forum enables them to build on and they can see how conceptual understanding progresses.*

These qualitative excerpts, in line with quantitative findings, suggest how students engaging more in knowledge building inquiry and knowledge forum might have more sophisticated beliefs about science learning and epistemic development. Knowledge Forum enables students to use and justify scientific knowledge and have interactions amongst ideas, which was important to their beliefs about the development of science as a changing subject. Such findings might support quantitative findings that the group actively participating in Knowledge Forum had significant changes in their epistemic beliefs. These findings are also consistent with pervious results showing how knowledge building might facilitate development of epistemic beliefs about science. (Lam & Chen 2012) and is consistent with findings elsewhere in the literature that students' epistemic beliefs can change from less to more sophisticated, given appropriate instructional interventions (Conley et al., 2004; Smith et al., 2000)**.**This also provide support that epistemic beliefs change occurs as a function of instructional environment or epistemic tclimate (Feucht, 2010; Muis, 2013; Muis, et al, 2015).

Conclusions and Implications

This study suggests that a knowledge-building environment, mediated by Knowledge Forum and reflective portfolio might be promising in fostering changes in students' scientific understanding and epistemic beliefs. The quantitative and qualitative findings provided preliminary but converging evidence of how students' participation and interactions in knowledge building inquiry, as well as the portfolio and reflection might influence students' scientific understanding and epistemic beliefs development. Our findings support the notion that technology-supported learning environments influence students' epistemic beliefs (Tolhurst, 2007; Tsai, 2008); Students' epistemic beliefs can change from less to more sophisticated, given constructivist practices in the classroom. (Muis,2013; 2015). This is consistent with Lam's (2012) and Lin (2015) findings that knowledge building environments are effective in fostering epistemic beliefs about science.

While epistemic beliefs are often considered individual endeavors as personal epistemology, our research suggests that student epistemology is best developed in collaborative learning and knowledge building environments when students work collaboratively to extend and create new knowledge. This study also has implications for research on knowledge building and epistemic beliefs using assessment and portfolio. The findings suggest that portfolios and reflections could be considered as formative assessment to both scaffold and to evaluate students' epistemic development. Our findings suggest the importance of considering students' epistemic and metacognitive processes in designing knowledge building inquiry, and highlight the importance of considering teachers' understanding aligning curriculum, design and student cognition. Ongoing analyses are being undertaken for qualitative analyses of teacher and students' understanding of epistemic growth, and further investigation is needed to explore the epistemic development process and to test the idea of knowledge building for epistemic change in multiple classes.

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Appendix 1. Epistemic Beliefs Questionnaire

Science Learning Questionnaire	Strongly Disagree				Strongly Agree
1. Most questions in science have one right answer.	1	2	3	4	5
2. The scientific ideas in science books sometimes change over a period of time.	1	2	3	4	5
3. You have to believe most things you read in science textbooks.	1	2	3	4	5
4. Learning science relates to everyday real-life problems.	1	2	3	4	5
5. Most scientific words have one clear meaning.	1	2	3	4	5
6. The answers to scientific questions change as you gather more information.	1	2	3	4	5
7. If you hear something about science from the scientists, you can be sure it is true.	1	2	3	4	5
8. Good answers are based on evidence from many different experiments.	1	2	3	4	5
9. You like working on science problems that have model answers.	1	2	3	4	5
10. New discoveries can change what scientists think is true.	1	2	3	4	5
11. You just have to accept answers from your teacher even though you do not understand them.	1	2	3	4	5
12. Forming your own ideas is more important than learning what textbook says.	1	2	3	4	5
13. If two people are arguing about a science problem, at least one of them must be wrong.	1	2	3	4	5
14. Some ideas in science today are different than what scientists used to think.	1	2	3	4	5
15. Only scientists know for sure what is true in science.	1	2	3	4	5
16. Ideas in science can come from your own questions.	1	2	3	4	5
17. All scientists would come up with the same answer to a scientific question.	1	2	3	4	5
18. Sometimes scientists change their minds about what is true in science.	1	2	3	4	5
19. Everybody has to believe what scientists say.	1	2	3	4	5
20. Putting our ideas together can develop a better theory of a scientific problem.	1	2	3	4	5
21. The most important part of doing science is coming up with the right answer.	1	2	3	4	5
22. What is true in science today will be true tomorrow.	1	2	3	4	5
23. If you read something in a science book, you can be sure it's true.	1	2	3	4	5
24. Good ideas in science can come from anybody, not just from scientists.	1	2	3	4	5
25. In science, there can be more than one way for scientists to test their ideas.	1	2	3	4	5
26. Scientists always agree about what is true in science.	1	2	3	4	5
27. It is good to have an idea before you start an experiment.	1	2	3	4	5
28. Scientific knowledge will not change over time.	1	2	3	4	5

Appendix 2. Items of the four dimensions in Science Learning Questionnaire

Factor item	Items in the questionnaire
Certainty (7 items)	1. Most questions in science have one right answer. 5. Most scientific words have one clear meaning. 9. You like working on science problems that have model answers. 13. If two people are arguing about a science problem, at least one of them must be wrong. 17. All scientists would come up with the same answer to a scientific question. 21. The most important part of doing science is coming up with the right answer. 26. Scientists always agree about what is true in science.
Development (7 items)	2. The scientific ideas in science books sometimes change over a period of time. 6. The answers to scientific questions change as you gather more information. 10. New discoveries can change what scientists think is true. 14. Some ideas in science today are different than what scientists used to think. 18.Sometimes scientists change their minds about what is true in science 22. What is true in science today will be true tomorrow. 28. Scientific knowledge will not change over time.
Source (6 items)	3. You have to believe most things you read in science textbooks. 7. If you hear something about science from the scientists, you can be sure it is true. 11. You just have to accept answers from your teacher even though you do not understand them. 15. Only scientists know for sure what is true in science. 19. Everybody has to believe what scientists say. 23. If you read something in a science book, you can be sure it's true.
Justification (8 items)	4. Learning science relates to everyday real-life problems. 8. Good answers are based on evidence from many different experiments. 12. Forming your own ideas is more important than learning what textbook says. 16. Ideas in science can come from your own questions. 20. Putting our ideas together can develop a better theory of a scientific problem. 24. Good ideas in science can come from anybody, not just from scientists. 25. In science, there can be more than one way for scientists to test their ideas. 27. It is good to have an idea before you start an experiment