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Scaffolding Reflective Assessment for Conceptual and Epistemic Changes Among Chemistry Students in Hong Kong

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Abstract: This study examined the design and process of how students' reflective assessment promoted collaborative metacognition for conceptual and epistemic changes, mediated by Knowledge Forum. The design involved knowledge-building inquiry with reflective assessment – Students wrote reflective summaries to track their initial understanding and trajectories of growth toward scientific understanding in the domain of electrochemistry. Two classes of 10th grade students in Hong Kong participated and results indicated stronger effects for the instructional class emphasizing knowledge-creation and reflective assessment compared to the Knowledge Forum class. Qualitative analyses showed how students' reflective assessment and collaboration helped them to develop metaconceptual and epistemic awareness as they examined their own and others' understanding. The analysis of inquiry threads highlighted the collaborative knowledge-building processes and the growth of community knowledge. A path analysis indicated that students' engagement on Forum predicted reflective collaboration that in turn exerted effects on their changes in conceptual understanding and epistemic beliefs.

Introduction

It is now widely accepted that science learning can be facilitated when students articulate their prior ideas and explain their understanding to each other. Conceptual change is examined emphasizing the social construction of knowledge and discursive interactions in the classroom (Scott, Asoko & Leach, 2007). Furthermore, researchers now question conceptual change as a sudden change or replacement of misconceptions with scientific ones through externally-driven conceptual conflict (Chan, Burtis & Bereiter, 1997). Instead, the conceptual change involves a gradual and complex process – the gradual revision of students' initial conceptual structures is mediated by students' intentional learning strategies (Sinatra & Pintrich, 2003). Current research on intentional conceptual change emphasizes the role of learners' metacognitive strategies, epistemic beliefs and agency in knowledge restructuring (Sinatra & Pintrich, 2003). It also points to the need to designing learning environments that encourage learners to employ goal-directed, reflective strategies and to develop metaconceptual awareness.

Researchers have argued that conceptual change involves not only changes in concepts; there needs to be changes in students' epistemic cognition and views about the nature of science (Duit & Treagust, 2003). Cognitive research has shown that students' epistemic beliefs can constrain or facilitate student thinking, reasoning, and science learning. For example, Stathopoulou & Vosniadou (2007) examined the relationship between physics-related epistemic beliefs and physics conceptual understanding amongst 10th grade students. Conley et al. (2004) attempted to investigate the changes in 5th grade students' epistemic beliefs in science, and findings indicated that students became more sophisticated in their beliefs about source and certainty of knowledge.

Vosniadou (2008) noted that conceptual change involves metaconceptual awareness – Students will be able to learn science concepts and principles only if they are aware of their prior understanding and the shift of their initial views toward scientific explanations. Therefore, it is necessary to design learning environments that facilitate students to become aware of their existing internal explanatory frameworks and beliefs. Increasingly the emphasis is to examine conceptual change that includes not only individual cognitive development but also social and collective aspects; socio-cognitive discourse plays a key role in facilitating conceptual change. Although there has been much progress indicating the role of metacognition and epistemic beliefs on students' conceptual change, most of the research are correlation studies. Fewer studies have examined designing for intentional conceptual change that brings about metaconceptual awareness with epistemic changes supported by social and collective discourse.

This study adopts an educational model, knowledge building, that emphasizes knowledge creation as a collective work of the community; and that knowledge is improvable by means of progressive discourse (Scardamalia & Bereiter, 2006). To support student discourse, Knowledge Forum (KF), a multi-media database constructed by students, was designed to support collaborative knowledge building discourse. In a knowledge-building community (both face-to-face and online), students engage in scientific discourse that involves posing cutting-edge problems, generating theories and conjectures, searching for scientific information, elaborating on others' ideas, co-constructing explanations, and revising their theories. Students' initial conceptual structures and learning pathways can be represented on the computer forum and thus become objects of inquiry for conceptual change.

There is now substantial evidence on role of knowledge building on students' collective inquiry and scientific understanding (e.g., Zhang et al., 2007). Despite major progress in two decades of research, there have been no systematic studies using this knowledge-building approach to examine conceptual change. Various principles advocated by researchers in conceptual change such as intentional goal-directed strategies, metaconceptual awareness, epistemic beliefs (see Vosniadou, 2008) are well aligned with knowledge-building. However, how collaborative knowledge building dynamics can bring about metaconceptual awareness and epistemic changes has not been examined. Further, we argue that knowledge building can enrich studies in conceptual change that often emphasizes small-group collaboration; there is a need to understand how conceptual change can take place in communities of learners and knowledge-builders. Knowledge building is not just a pedagogical approach but a theory of epistemology; so how students working with knowledge might change their epistemic views are fruitful lines of inquiry. Finally, knowledge-building research on science learning, in many cases, has been conducted with elementary-school children. It would be useful to extend the scope of inquiry to investigating knowledge building for high-school science.

This study employed a design developed in research on assessment of knowledge building that involves students assessing their own collaboration (Lee, Chan, & van Aalst, 2006; van Aalst & Chan, 2007). Research has shown that students assessing their own scientific inquiry promoted metacognition (White & Fredericksen, 1998). Similarly, student-directed e-portfolio assessment with students documenting how they collaborated in knowledge-building discourse fostered their domain understanding (van Aalst & Chan, 2007). This study extends this line of inquiry: We designed knowledge building for conceptual change focusing on promoting metacognition in collaborative context. As with other research on knowledge building, students engaged in emergent collaborative inquiry on the forum. In this study, we further asked students to reflect on their prior conceptions and to track how they moved towards scientific understanding as they considered others' contributions and revised their ideas.

To iterate, this study aimed to design and examine how reflective assessment with collaborative dynamics would promote metaconceptual and epistemic awareness for conceptual change. Two research questions were included:

(1) What were the effects of knowledge building augmented with reflective assessment on students' conceptual and epistemic changes ?

(2) How did students' reflection contribute to their changes in conceptual and epistemic understanding ? and what were the relations among knowledge-building dynamics, conceptual change and epistemic growth ?

Methods

Participants

Eighty 10th graders (Age ranging 15-16) in two chemistry classes in Hong Kong participated in this study. The lessons were conducted in English and students wrote notes in English on Knowledge Forum (KF). Both classes engaged in knowledge-building inquiry - The first class is called Knowledge Forum (KF, n = 40) and the second Reflective Assessment with Scaffolds (RAS, n = 40). Both classes were taught by the same teacher, who had taught high-school chemistry for more than twelve years and had used knowledge-building pedagogy for over 6 years.

Procedure

This study was conducted in the second semester of 2008-09 academic year lasting from Feb-June (16-18 weeks). There were five chemistry lessons each week; each lesson was of 35 minutes duration. In both classes, students learned electrochemistry – They were initiated into a community emphasizing collaborative inquiry; they wrote computer notes and continued their discussions on Knowledge Forum after school. Both classes had similar activities and they wrote on Knowledge Forum; there was however an emphasis on building up the knowledge-creation and reflective assessment culture in the instructional class. In particular when writing reflective diaries, they used conceptual-change scaffolds including (e.g., *My initial ideas, What we think, What I think now)*. Both classes used the same instructional topics, textbook and reference materials, and conducting the same chemistry experiments. Students in Hong Kong wrote on Knowledge Forum at home and integrated their understanding with face-to-face discussion and inquiry in class.

Designing a Knowledge-Building Environment

We designed the learning environment based on knowledge building pedagogy *aligning that with conceptual change principles* (Vosniadou & Kollias, 2003). The principles and activities of the design are briefly described:

(1) *Activate prior knowledge through classroom discourse*

Students need to activate and reflect on prior knowledge and to articulate their ideas for science learning. Students worked in dyads/groups discussing science phenomena/problems in classroom (e.g. how do you compare the lifetime of different kinds of batteries?). Students were scaffolded to present their ideas, make observations of inquiry-based experiments; raise questions they did not understand, elaborate and comment on others' views. Students' ideas were shared and made public using concept-maps, posters and knowledge-building walls (boards for posting ideas). When students became familiar with articulating their thinking, they then continued their inquiry and contributed their ideas and questions onto the Forum (Figure 1 left).

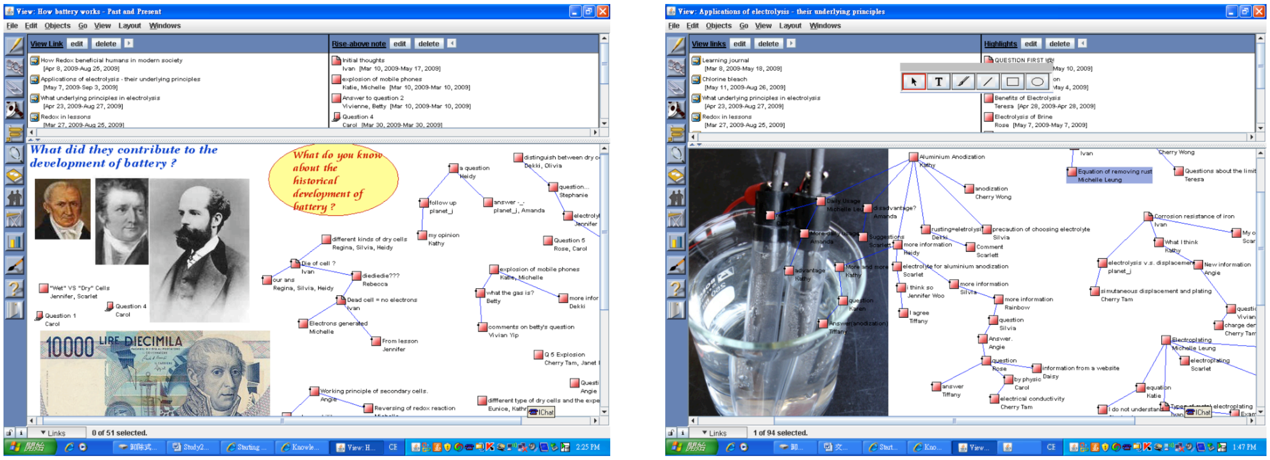


Figure 1 First view on Knowledge Forum (left) and view on emergent inquiry from students (right).

(2) *Foster metacognition through KF scaffolds and problem-centered inquiry*
Students were encouraged to raise authentic problems from prior understanding and daily life on electrochemistry that puzzled them (e.g. what causes the explosion of mobile phones?). Extending their inquiry in classroom, students wrote into discussion views on Knowledge Forum: Students engaged in goal-directed inquiry – they posed problems, made conjectures and hypotheses, co-constructed explanations, compared different explanations and revised their understanding. KF scaffolds including '*I need to understand*', '*My theory'*, '*New information*', and '*A better theory'* prompted metacognitive thinking and theory revision (Figure 1 right). Teacher facilitation involved helping students notice conflicts, discrepancies and identifying gaps for further inquiry.

(3) *Develop deep understanding through model-based explanatory inquiry*
Students were involved in constructing models of chemical cells using different fruits in chemistry classes. They investigated the possible factors that might affect the maximum voltage of their constructed fruit cells, and continued the KF discussions to postulate the working principle of their designed fruit cells. Students compared different models and co-constructed their explanations through the collaborative idea-driven inquiry (Figure 2).

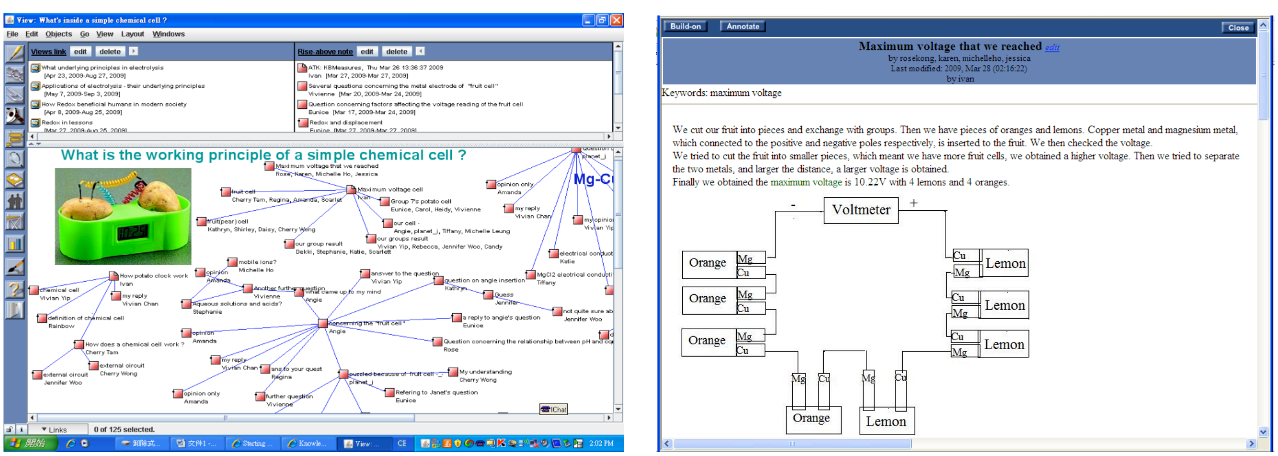


Figure 2 View on model-based explanatory inquiry (left) and students' note on their model of fruit cells (right)

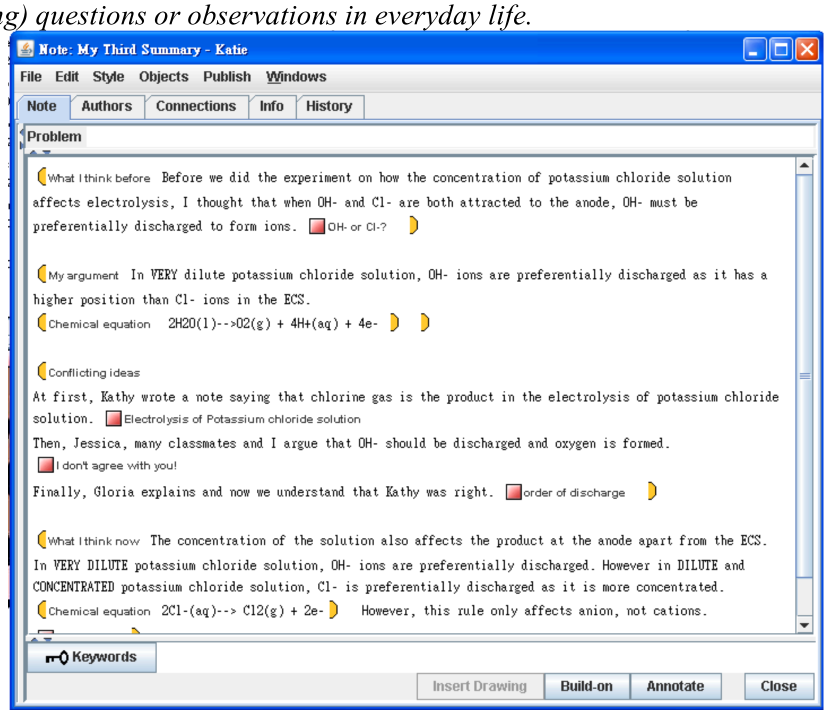
(4) *Integrate fragmented ideas and use 'rise-above' explanation*

To tackle the problem of fragmented ideas, a common barrier to conceptual change, students deepened their understanding using KF functions of 'rise above' and 'references' to synthesize diverse and fragmented ideas from classmates as they worked towards more *coherent explanations.* Teachers integrated forum's diverse ideas/theories and fragmented questions with classroom talk to help students deepen their inquiry. The classroom discourse provided collective cognitive responsibilities among students to sustain asynchronous knowledge building at home.

(5) *Develop metaconceptual awareness through reflective assessment*

In both classes, students were asked to review notes on forum, reflect on their initial beliefs and track their changing ideas incorporating classmates' ideas (Figure 3): The prompt was: You are encouraged to review the computer notes written by you and your classmates in the database. Write a summary note to reflect and to consolidate what you have learnt from the views of '*Batteries' &* '*Simple chemical cell*'… In writing the reflective summary, you may select relevant computer notes (reference) as evidence that support your understanding. Think about how your chemical knowledge has developed or changed. Students of the Reflective Assessment with Scaffolds (RAS) class were emphasized to track their conceptual and epistemic changes in their reflective assessment. They were further provided with additional conceptual-change scaffolds such as "My initial idea", "Our misconception", "What we think together", "What I think now" and "My belief on learning & knowledge". Students could also use other KF scaffolds such as "This theory cannot explain", "A better theory" and "Putting our knowledge together".

Teacher scaffolded student reflection as formative assessment integrating reflection into ongoing work. For example, he wrote: *So far I have observed some benefits of chemistry gains from your summaries, (1) You are encouraged to give more evidence (chemical knowledge) to reflect on your understanding or knowledge gains (not just say KF is good). (2) It may be useful to tell us more of your initial thoughts and final thoughts on a particular chemistry concept. (3) Continue to build on others' notes to deepen your ideas after reviewing these previous notes. Of course you can continue to raise other (emerging) questions or observations in everyday life.*



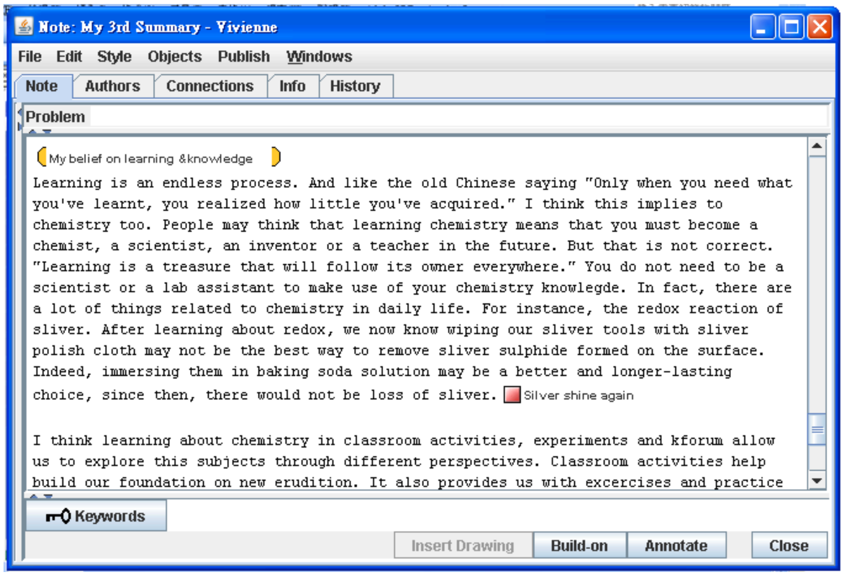


Figure 3 Examples of reflective summary notes from RAS class.

Results

We first assessed student changes in conceptual and epistemic changes after the instruction; we then examined why and how such changes might take place relating to knowledge-building inquiry, reflection and inquiry threads, and finally we investigated the relations among knowledge building activities, conceptual-change learning and epistemic changes.

a) Conceptual-Change Learning in Electrochemistry

<u>Conceptual-Change Written Tests and Explanation</u>

Written questions were designed to tap into students' understanding of electrochemistry probing into students' alternative conceptions. The written questions were designed based on studies on conceptual-change in electrochemistry in science education research. Questions included open-ended ones asking students to explain their understanding of key concepts to probe their conceptions (what is reduction?). Responses to forced-choice questions were coded on students' explanations of their choice. The pretest and posttest percentage scores were 13.8 (7.1) and 57.3 (12.3), and 14.1 (6.4) and 49.1 (15.4) for Reflective Assessment with Scaffolds (RAS) and Knowledge Forum (KF) classes, respectively. Analyses of pre-posttests using paired *t*-tests showed that both classes improved on the conceptual-change tests with RAS, t (39), = 20.14, p<.001, and KF, t (39), = 14.21, p<.001. Analyses using ANCOVA controlling for pre-test differences indicated that higher scores were obtained for students in Reflective Assessment with Scaffolds (RAS) compared to KF class.

<u>Changes in Alternative Conceptions in Written Tests</u>

The number of alternative conceptions (misconceptions) for each student was identified from their responses to the written tests. The means of alternative conceptions were 6.4 (1.7) and 5.7 (1.2) at pretests, and 1.9 (1.5) and 3.0 (1.9) at posttests for Reflective Assessment with Scaffolds (RAS) and Knowledge

Forum (KF) classes respectively. Students in both classes decreased in the number of alternative conceptions after instruction. ANCOVA indicated that there were more decreases in the number of alternative conceptions for students in the condition with scaffolds (RAS).

b) Changes in Epistemic Beliefs

Students were administered a 28-item questionnaire on epistemic beliefs (adapted from Conley et al., 2004) to examine the ways students think about the nature of knowledge. The questionnaire was piloted tested with over 300 students and validated in our earlier study (Lam & Chan, 2008). Consistent with the earlier study, three factors were identified (1) "Certainty-Source", (2) "Development" and (3) "Justification" with scale reliabilities ranging from 0.64 to 0.83. An example of an item on Certainty is "Most questions in science have one right answer"; an example of an item on Development is "Scientific knowledge will not change over time", and an example of an item on Justification is "Ideas in science can come from your own question".

Table 1: Pre- and posttest epistemic beliefs mean scores on subscales and overall across classes

Dimension	RAS class (n = 40)		KF class (n = 40)	
	Pretest	Posttest	Pretest	Posttest
Certainty-source	3.28 (.43)	3.49 (.38)	3.41 (.36)	3.39 (.41)
Development	3.75 (.49)	4.01 (.43)	3.85 (.49)	3.95 (.40)
Justification	3.99 (.44)	4.08 (.32)	3.90 (.56)	4.06 (.42)
Overall	11.03 (.94)	11.58 (.88)	11.17 (.99)	11.40 (.85)

Paired sample *t*-tests showed that students in both classes made changes towards more sophisticated epistemic beliefs based on the overall scores, for RAS, $t\ (39) = 4.73$, $p<.001$ and for KF, $t\ (39) = 2.27$, $p<.03$. Separate analyses showed that students in RAS improved more on the subscales of "certainty-source" [$t\ (39) = 3.83$, $p = .000$] and "development" [$t(39) = 4.39$, $p = .000$] whereas students in KF improved more on "justification" [$t\ (39) = 2.32$, $p< .03$].

c) Students' Knowledge Forum Engagement and Collaborative Reflection

Knowledge Forum Engagement (ATK)

We examined students' overall participation and engagement in Knowledge Forum using software called the Analytic Toolkit (ATK, Burtis, 1998) that uses log files to show students' participation and activity on the forum. We included several ATK indices commonly used in knowledge-building research : (1) number of KF note written, (2) % of notes read, (3) % of linked notes, (4) scaffolds (thinking prompts) (5) keywords and (6) revision. Some of these indices show student collaboration (e.g., notes read/linked) and others reflect metacognition such as the use of "scaffolds" and "revision" of notes for purposeful activities.

There were 858 written notes in 8 views contributed by RAS class and 904 written notes in 5 views contributed by KF class over the period of 10 weeks. Results of ATK indices indicated substantial usage of the databases in RAS and KF classes: number of notes written per author, 21.5 and 22.6 notes; percentage of notes read, 55% & 47%; note-linked, 80% and 68%; and scaffolds, 21 and 9.0, respectively. Although there were no norms for ATK, comparison with other studies indicated that these students were engaged actively participating and collaborating on KF. Compared to the literature on online learning with fragmented contribution (Hewitt, 2003), these numbers indicate high level of contribution; they are also comparable to those identified in mature knowledge building communities (Zhang et al., 2007).

<u>Reflective Assessment and Collaborative Reflection</u>

As described above, students wrote three reflective summaries to reflect on their initial and new ideas in electrochemistry based on their discourse. These reflective summaries were scored on a 6-point scale. At the lower levels (1-2), the reflection depicts that students were just describing new information with limited reflection on what it meant for their conceptions. At the mid-levels (3-4), students demonstrated some personal thinking for identifying misconceptions or knowledge gaps in their understanding. At the higher levels (5-6), students reflected on their prior knowledge, identified gaps, considered how others' ideas supported their reflection; they demonstrated metaconceptual awareness of initial and new ideas and noted how they changed in their understanding of some concepts. The summaries were coded and currently inter-rater reliability checks were being conducted. Figure 4 and 5 show the mean scores of three reflective summaries of two classes and average use of scaffolds in writing three reflective summaries of two classes respectively.

Figure 4 Mean scores of reflective summaries of two classes

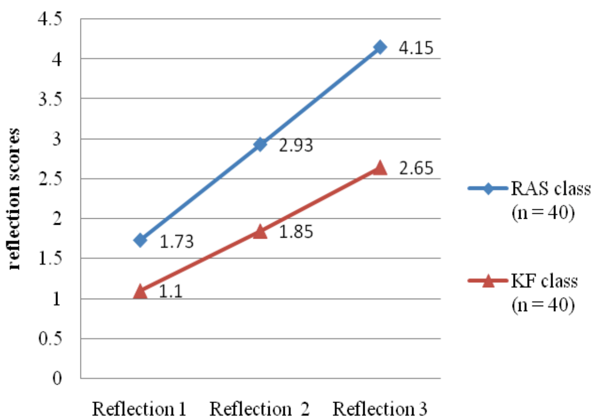
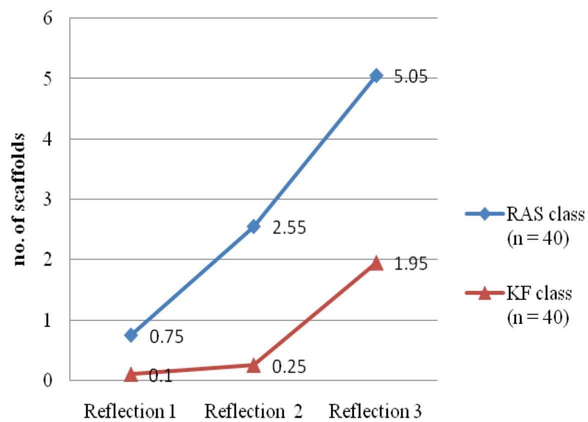


Figure 5 Average scaffolds use in reflective summaries of two classes



Students of both RAS and KF classes made more sophisticated reflection over time, and the RAS class improved more significantly on metacognitive reflections than the KF class. Similarly, both classes used more scaffolds (thinking prompts) in structuring the reflection over time, and the RAS class had significantly more scaffold uses than the KF class in all reflective summaries. Interestingly, the combined scores of three reflective summaries are correlated with the total scaffold uses in each class, RAS class: r = .31, p<.05; KF class: r = .43, p<.01. It was suggested that the more use of scaffolds in reflection could enhance students' metacognition in collaborative context. In the following, two contrastive examples of reflective summaries are provided to suggest how collaborative reflection may foster metaconceptual awareness for conceptual and epistemic growth.

Table 2: An Example of a Reflective Summary Note (Low-Level Response)

Restating Information	Excerpts from the Reflective Summary Note
States impartial information	In the simple chemical cell, I found out that a potato cell can actually conduct electricity and drive the calculator to work. …
Makes reference to one note; no reference to one's own thinking	Through Florence's note, I knew that the electromotive force within each potato makes to move electric current. And the copper wire makes the electrons move in the potato, causing energy to move into the clock. This let me know more about how a potato cell conducts electricity…
Describes factual information and formulae; no reflection	In the redox reaction of copper, I knew that …when the copper reacts with oxygen, copper acts as the reducing agent and causes oxidation, while oxygen acts as the oxidizing agent, causes reduction : $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$ And when hydrogen reacts with the copper oxide, hydrogen acts as the reducing agent, reduce the copper oxide : $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$…

Table 3: An Example of a Reflective Summary Note (High-Level Response)

Reflective Metacognition	Excerpts from the Reflective Summary Note
The student reflected on her understanding on state of matter and electrolysis	
- Identifies her prior conception; reflects on the source of difficulty - Considers role of textbook information	What I think before The products of electrolysis are always the same as long as the chemical salt is the same, disregarding its state. -*Because in many previous textbook chapters such as molarity, water plays no role* in the sense that it does not react.[1] What I think I thought we do not melt the salt in electrolysis just because it is too troublesome.
- Considers other ideas and explanations - Selects relevant ideas and organizes them to show some learning pathways (e.g., further)	What we think together Jennifer provides detailed chemical equations to explain the difference[2] Agree. Candy *further* provides the significance of the difference[3] *molten and aqueous*, that metals like sodium could never be formed in electrolysis if there were no molten sodium salts…She also mentioned an interesting fact that mercury electrode can be used to extract pure sodium. This thought is *further worked* on.[4] Mercury electrode
- Reflects on new idea - Continues to query gap of understanding	When doing work regarding electrolysis, I have to look carefully whether the chemical is *molten or aqueous* as the results are very different. *However I still do not understand* the working principles of mercury electrodes.
The student noted another cycle examining factors influencing electrolysis	
- Reflects on prior beliefs; notes prior gaps in understanding; - Identifies source of confusion & difficulties - Refers to textbook as conveying information not in real science	What I think before As stated above, *I thought* the products of electrolysis are always the same if chemical salt is the same. *I didn't think a* higher voltage, except speeding up the process, will produce other results. For example, in aluminum anodization, *I thought only* the quality of the original aluminum will provide different results. Moreover, although I noticed that the metal deposited on the electrode is unevenly distributed, *I always thought* it was due to our poor skills or equipment. I have not considered it a natural occurrence*, mostly because textbooks often show the electrode fully and smoothly covered with the metal.*
- Considers others' ideas - Identifies puzzling information and reflects on what she does not understand;	What we think together …Rainbow suggested that temperature as well as acidity affects the results. *She also gave a curious suggestion that lower temperature gives thicker layer of aluminum oxide, which I still can't understand* as I thought a higher temperature facilitates reaction, like what angie said[6] Answer..[7] more information Cherry Wang further told us that an unsmooth layer is resulted as the metal plated is

- Examine various ideas and explanations to help her move toward better Understanding	attracted to external corners and avoids internal ones. [8] Effects and Limitations of electrolysis. Besides, a higher current can lead to the formation of other substances in the solution, as mentioned in [9] 2 substances formed?
Reflects on new understanding	What I think now The product of electrolysis could be affected by various [external] effects; the metal plated does not naturally spread out evenly.
The student included another scaffold and reflect on her beliefs and knowledge	
Reflects on beliefs about knowledge pointing to coherence (structure of knowledge) and evidence in justification	My belief on learning &knowledge The most useful part is it broadens our thinking by *relating one topic to another*. For example I have never considered rusting from a redox or electrolysis point of view. *I believe we could learn more if we try to search for information before writing the notes instead of guessing without any evidence…*

Note: 1. What I think – Scaffolds in reflective summaries
2. [3] Reference notes in summaries with hyper-links to students' notes in the database

Table 2 shows an example of a summary note in which Student A was not actually engaged in reflection – She described some impartial information; referred to only one note from a classmate, described some factual information and formulae but did not reflect on her prior knowledge or made attempts to describe changes. Table 3 shows another example with two related episodes – In the first one, Student B identified her prior understanding (state of matter & electrolysis); it is a key concept and a common alternative conception. She reflected on why she had the problem (prior knowledge & textbook); considered various classmates' explanations and organized them; and she noted her new understanding but continued to identify areas she did not understand (mercury electrode). In the second episode (factors influencing electrolysis), Student B continued to identify her prior ideas and gaps of understanding; noted others' ideas and she puzzled over her classmate's curious information. She tracked different ideas but focused on the original problem and reflected on her new understanding. Student B employed good use of the scaffolds and demonstrated metacognition noting what she knew and what she did not understand. As well, she showed metaconceptual awareness as she became more aware of her initial conceptions and how they differed from more scientific ideas. There are various instances that showed how such reflection prompted Student B to examine nature and source of knowledge. For example, she noted textbook as unauthentic science and "imperfect" source of knowledge. Furthermore, she concluded using the scaffold My belief on learning & knowledge implying some thinking about the importance of coherence (structure of knowledge) and role of evidence.

d) Inquiry threads analysis on knowledge building discourse

An inquiry thread consists of a series of discourse entries that address a shared principal problem and constitute a conceptual line of discussions/inquiry in a community knowledge space (Zhang and Chan, 2008; Zhang, et al., 2007, 2009). Inquiry threads analysis indicated the growth of community collective knowledge based on the discursive notes in the Knowledge Forum. Figure 6 and 7 shows a network of inquiry threads that maps out the knowledge building discourse of RAS class and KF class, respectively, investigating the topic of electrochemistry over a 10-week period. Fifteen and eleven conceptual threads emerged from the discourse of RAS and KF class, respectively. The contributions by the teacher were also taken into the analysis. The numbers following the title of each thread indicate the *number of notes contributed*, *authors* and *readers* involved, respectively.

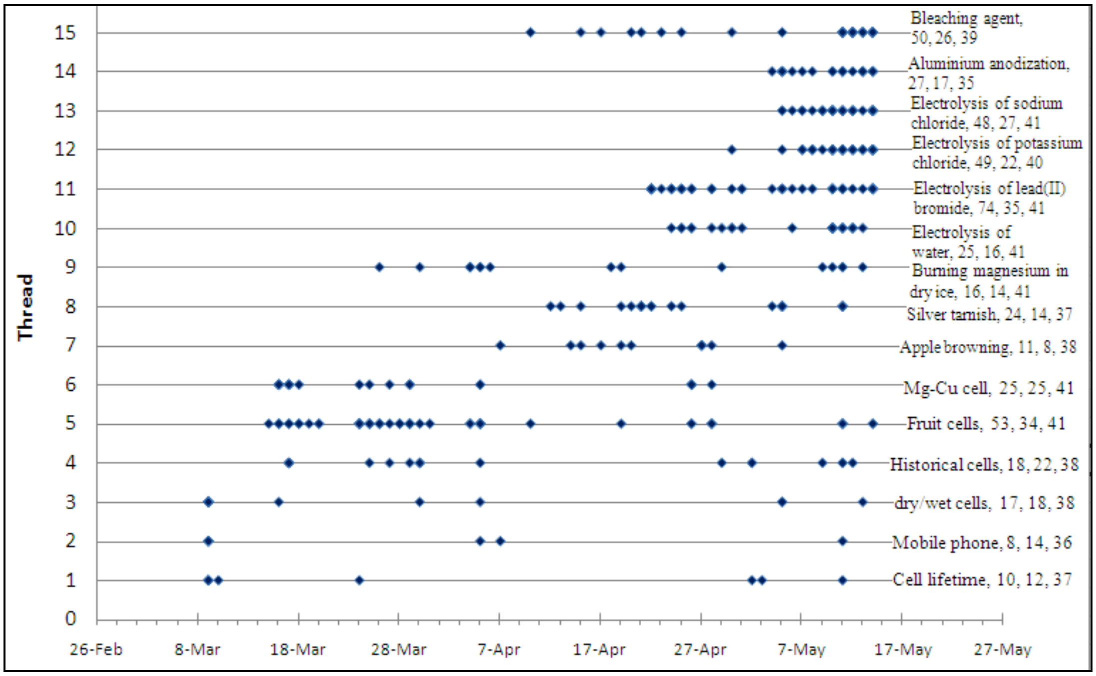


Figure 6 A network of inquiry threads emerged from RAS class.

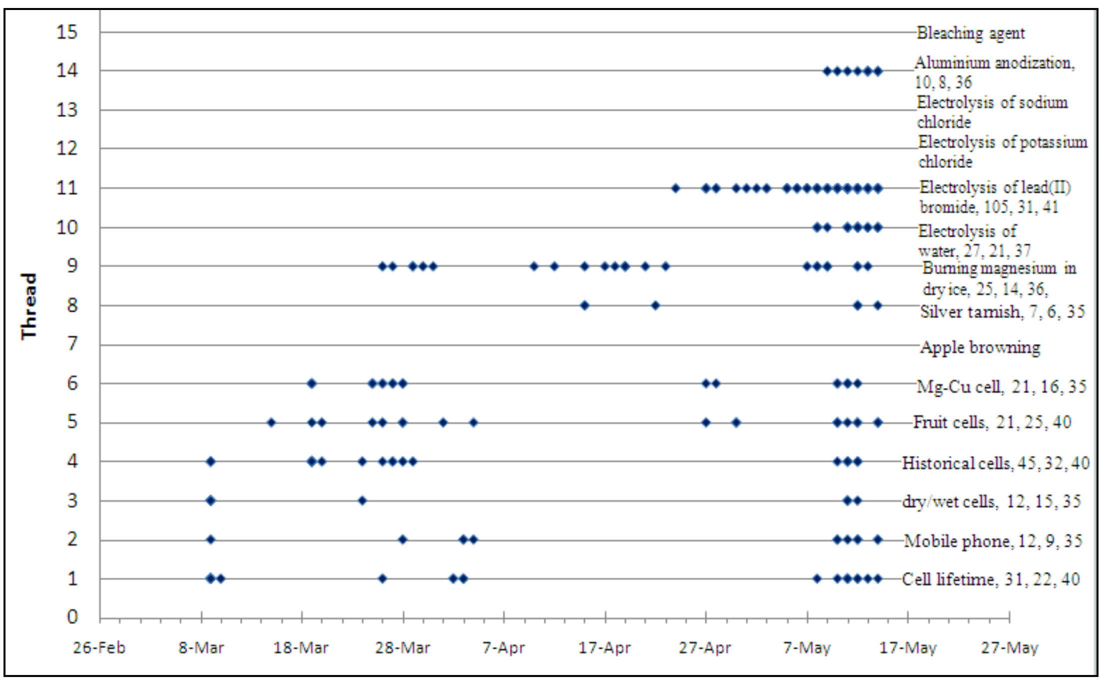


Figure 7 A network of inquiry threads emerged from KF class.

The progressive advances of community knowledge in an inquiry thread can be further examined through content analysis of theme-based discourse on a 4-point scheme (Table 4).

Table 4: Rating scheme of content analysis of inquiry threads

Point	Description
1	The discussion notes show fragmented facts on the shared problem and demonstrate pre-scientific understanding on the conceptual problem.
2	The discussion thread shows elaborated facts on the shared problem and demonstrates conceptual understanding from pre-scientific to scientific ideas.
3	The collaborative discourse involves explanations of scientific ideas to deepen the problem solving. The productive questions, new information and diverse ideas generated in the community moves to deepen the collective understanding of a focal problem.
4	The collaborative discourse involves scientific explanations to respond the knowledge gap or misconceptions identified. The progressive problem solving discourse demonstrates conceptual changes or epistemic growth to generate collective community knowledge.

Table 5: Knowledge advances of inquiry threads of two classes

Inquiry thread		Rating of inquiry threads	
		RAS class	KF class
1	Cell lifetime	1	1
2	Mobile phone	2	2
3	Dry / wet cells	2	2
4	Historical cell	2	3
5	Fruit cells	4	2
6	Mg-Cu cell	3	2
7	Apple browning	2	---
8	Silver tarnish	3	1
9	Burning magnesium in dry ice	3	3
10	Electrolysis of water	4	3
11	Electrolysis of lead(II) bromide	3	3
12	Electrolysis of potassium chloride	4	---
13	Electrolysis of sodium chloride	4	---
14	Aluminium anodization	3	1
15	Bleaching agents	3	---

Note: --- indicates the problem theme not to be found in the views of KF

Table 5 shows a larger number of inquiry threads associated with higher levels (3-4) of rating emerged from RAS class than KF class. Qualitative analyses of inquiry threads indicated that the RAS class involved more contributions in intensive discourse, raised deepening questions, generate and refine ideas through various sources of information than that of KF class. It was suggested that the RAS class is associated with more dynamic knowledge advances in the knowledge-building discourse that may lead to more conceptual changes and epistemic growth than KF class.

e) Contribution of Knowledge Building Participation and Reflection to Conceptual & Epistemic Changes

Correlation Among Measures

Table 6 shows the correlation among various measures to test an overall model of the relations among Knowledge Forum participation, knowledge-building reflection and subsequent conceptual and epistemic changes. The two classes were combined to maximize variation. To improve the coherence for analyses, the various ATK forum indices were combined using factor analysis (see Lee et al., 2006). Two factors were extracted, Factor 1 is called **metacognition** (scaffold use, note revision and keyword) that explains 32.6% of the variance, and factor 2 is called **collaboration** (notes created, notes linked and read) that explains 30.1% of the variance. Table 6 indicates that KB reflection was significantly correlated with ATK metacognition, changes in conceptual tests and epistemic beliefs scores. Furthermore, ATK collaboration scores were significantly correlated with conceptual-change scores.

Table 6: Correlations among Forum participation, KB reflection, conceptual and epistemic measures

	1	2	3	4	5	6	7	8
1.ATK Metacognition								
2 ATK Collaboration								
3. KB Reflection	.57***	.18						
4. Pre-Epistemic Belief								
5. Post-Epistemic Belief				.71***				
6. Epistemic Belief Change			.27*	-.50***	.26*			
7. Pre-Conceptual								
8. Post-Conceptual		.38**	.44**					
9. Conceptual-Test Change		.31*	.40**				-.32*	.90***

Note: * p<.05; **p<.01; ***p<.001

Regression and Path Analyses

We conducted hierarchical regression analyses on students' post-conceptual scores first using exam results and pre-conceptual scores (prior achievement) as predictors (R^2 =.34). When forum engagement (ATK Collaboration) was added, additional 4.6% variance was explained (R^2 =.38). Further, when we added reflection scores, there were additional 7.4% variances explained (R^2 =.46); R^2 changes were all significant. These results indicated that over and above science achievement and prior knowledge, student engagement in forum and metacognitive reflection further contributed to post-test conceptual scores (Table 7).

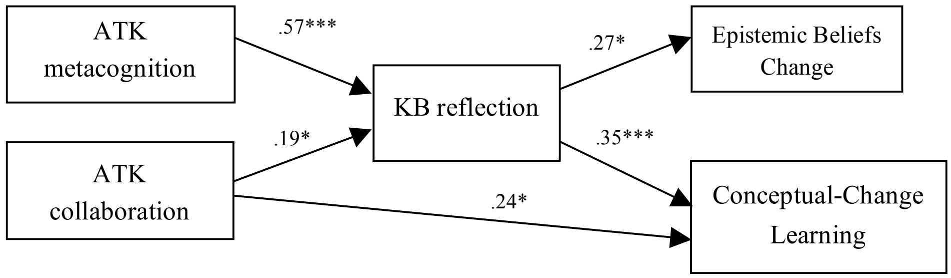
Table 7: Regression on post-conceptual scores with achievement, Forum collaboration & reflection as predictors

	R	R^2	R^2 Change	F Change
Mid-year exam & pre-conceptual scores	.58	.338	.338	19.66***
Forum – ATK collaboration	.62	.384	.046	5.63*
Knowledge-Building Reflection	.68	.458	.074	10.3**

Note: *p<.05; **p<.01; ***p<.001

We also employed a path analysis testing a causal model to provide a more coherent picture: Student engagement in Knowledge Form including both metacognition (e.g., scaffold use; notes revision) and collaboration (e.g., notes read and linked) predicted depth of collaborative reflection that further exerted effects on students' changes in conceptual written tests and epistemic beliefs scores.

Figure 8 A path analysis indicating contributions of knowledge-building activity to conceptual and epistemic changes



Discussions and conclusions

This study developed a knowledge-building environment augmented with reflective assessment to examine and to foster conceptual change and epistemic growth. Results indicated that after the instruction, students in both classes changed towards more sophisticated scientific understanding measured by conceptual-change tests in electrochemistry. There is some evidence suggesting students also made some shifts in their epistemic beliefs. The effects were stronger for students in the class focusing on knowledge-creation design compared to the Knowledge Forum class.

A key question to address is to examine knowledge-building dynamics and to explain the pre-posttest gains, that is, how it may be possible for students to experience these changes. We demonstrated that asking students to engage in knowledge-building inquiry and *to assess their own scientific understanding* in their discourse could help them activate prior knowledge, engage in metacognitive regulation, develop meta-conceptual awareness, and reconstruct fragmented views into more coherent explanations. As the excerpt shows, the student identified her prior conceptions; examined the nature of difficulties; considered others' views; puzzled over gaps of understanding; and integrated fragmented ideas into a more coherent account. The excerpt also suggests metacognitive reflection was facilitated because of the rich collaborative context with diverse ideas from classmates.

Although ATK forum indices are quantitative, the extent to which students engaged in KF was a prerequisite for deeper conceptual work – It supports the notion of how CSCL may provide the medium through which students can articulate, represent, interact and inquire into their ideas for sustained inquiry. Regression analyses provided support of this account indicating that students' engagement on forum and deep collective reflection predicted post-test conceptual scores *over and above* their academic achievement. A path analysis further showed that students' forum activity predicted their collaborative reflection that in turn influenced students' posttest conceptual and epistemic changes.

Regarding epistemic shifts from questionnaire data, the excerpt provided some glimpses suggesting how changes were possible in collaborative inquiry and reflection. For example, Student B reflected upon the textbook as a source of 'imperfect" knowledge decontexualized from real-world science (i.e., textbook pictures always show smooth surface). She also pondered upon the importance of the connection among topics (structure of knowledge) and the need for justification using evidence. When students tackled authentic problems and reflected on their changes in understanding, they might be better able to see that knowledge is not certain and that it can be advanced.

To summarize, the study furthers research on knowledge building aligning with conceptual change augmented with student-directed assessment (van Aalst & Chan, 2007). Whereas many studies have demonstrated the role of metaconceptual awareness and epistemic beliefs, this is one of the few studies that illustrated how it might be possible to foster conceptual, metaconceptual and epistemic changes through collective reflection with a knowledge-creation design model. Instead of eradicating misconceptions, students' prior understandings could become objects of collective inquiry. Metacognition for conceptual change is not an individual accomplishment but one that can be examined and fostered in a community of knowledge builders. Current analyses are being undertaken comparing different levels of inquiry threads to examine more closely how conceptual and epistemic changes are mediated by knowledge-building dynamics and discourse moves.

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