

## Students Assessing Their Own Knowledge Advances in a Knowledge Building Environment

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**Abstract.** We describe the design of a knowledge-building environment and examine the roles of knowledge-building portfolios in characterizing and scaffolding collaborative inquiry. Three classes of Grade 9 students in Hong Kong used Knowledge Forum (KF) under several design conditions. Results showed (1) Students working on portfolios guided with knowledge building principles showed more participation, deeper inquiry and conceptual understanding than students working on KF only, or producing KF portfolios with no principles, (2) Students' knowledge-building inquiry and discourse were related to their conceptual understanding, and (3) Knowledge-building portfolios provided ways for identifying and characterizing collective knowledge advances in the community.

**Keywords:** Knowledge building, assessment, portfolios, inquiry, computer discussion forums

### INTRODUCTION

There is now increased evidence of the cognitive benefits of computer supported collaborative learning. Research using asynchronous networked environments has shown how they help students advance understanding and inquiry, construct knowledge socially, and develop subject-knowledge understanding (CaMile, Guzdial, & Turns, 2000; Knowledge Forum, Scardamalia & Bereiter, 2003). Despite much progress, there remain questions regarding the integration of assessment, instruction and curriculum in CSCL classrooms, and specifically about the design of assessment to support and characterize learning and collaboration in classroom context.

Whereas networked computer discussion is becoming increasingly popular, many challenges and difficulties exist pertaining to the quality and variability in student participation (Hewitt, 2003; Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003). As well, there are issues concerning teacher assessment of students learning. Investigators have come to recognize that asking student to interact and discuss on computer forums does not necessarily lead to high-quality discourse. Hence the questions, How can students best learn about inquiry and collaboration when engaging in computer-supported discourse? How can classroom assessments tap into the theoretical nature of collaborative process while providing pedagogical support in scaffolding student understanding? This study examines the designs and roles of electronic portfolio assessments in characterizing and fostering collaborative inquiry in the context of Knowledge Forum, a computer-networked learning environment (Scardamalia & Bereiter, 2003).

### Knowledge Building as Collective Cognitive Responsibility

In this paper, knowledge building is defined as "the production and continual improvement of ideas of value to a community" (Scardamalia & Bereiter, 2003, p. 1370) emphasizing 'improvable ideas' and 'collective cognitive responsibility.' Similar to the process of scientific and scholarly inquiry, ideas are viewed as conceptual artifacts that can be examined and improved by means of public discourse within the knowledge-building community. In knowledge-building communities, students make progress not only in improving their personal but also in developing collective knowledge through progressive discourse. Knowledge building, according to Scardamalia (2002) may be summarized in a set of twelve knowledge building principles (i.e., epistemic agency, improvable ideas, community knowledge, diversity of ideas, rise-above, authentic problems, constructive uses of authoritative sources) identifying distinctive features and dynamics of the process.

To support working with knowledge, Knowledge Forum™ (KF), a web-based discussion forum, has been designed. A KF database is entirely created by students. Using networked computers, a number of users can simultaneously create notes (text or graphics) to add to the database, search existing notes, comment on other

students' notes, or organize notes into more complex structures. The communal database serves as an objectification of the community's advancing knowledge. Features of KF are designed to help students reframe and advance ideas. For example, when writing a note in KF, students can add other notes as references, thereby creating an integrated web of notes (ideas) as their work proceeds. The visual linkages between ideas provide an important image for students, reflecting the interconnected and dialogical nature of knowledge that underpins the knowledge building perspective. Scaffolds or sentence starters such as 'My Theory' and 'I Need to Understand' are metacognitive prompts that can also be used to make the communicative intent of the information clear. For example, the scaffold 'My Theory' indicates that the information presented in the note is conjectural, and that it should be subjected to critique, testing, and application.

### **Learning, Assessment, and Collaboration**

A major thrust of CSCL studies is quantitative and qualitative analyses of collaborative processes, and evaluation and assessment of systems and designs (e.g., Dillenbourg, Eurelings, & Hakkarainen, 2001; Stahl, 2001). Yet much less attention has been given to *formative, embedded, and transformative* aspects of assessment in collaborative inquiry, that is, how assessment can be used to *scaffold* students' collaborative inquiry and understanding. Analyses of computer discourse in computer networked environments and forums are common; current approaches focus on researcher-designed tools and analyses; but few are designed to provide *scaffolds* or to foster *agency* for students in CSCL classrooms. Despite the popularity of forums and networks, investigators have come to realize that putting students together does not mean they will engage in collaborative inquiry and deep discourse. Problems exist with low and variable participation rates and quality of discourse. In the following, we examine several issues about the alignment of learning, assessment and collaboration:

#### ***Assessment of Learning and Assessment for Learning***

There have now been major shifts in paradigms of learning and instruction, and current views propose that assessment play the dual roles of scaffolding learning and measuring it (Bransford, Brown, & Cocking, 1999; Black & William, 1998; Gipps, 2002; Shepard, 2000). Assessments need to be designed so that they are parts of the instructional processes in fostering learning. The scaffolding aspect of assessment, sometimes called assessment *for* learning (Black & William, 1998), involves designing assessments in ways that foster learning. Despite major shifts in assessment reforms, little work has been conducted in aligning learning, assessment with collaboration in CSCL settings. Even though high-level goals are professed in computer-based instruction, when it is time for assessment, superficial knowledge is often emphasized (Chan & van Aalst, 2004; Reeve, 2000). Students need to be given the agency to assess their own and community knowledge advances. Assessment should be designed as a tool that both *measures* and *fosters* deeper inquiry and collaboration.

#### ***Assessment of Individual and Collective Aspects of Learning***

Collaboration is valued in a wide range of social constructivist learning approaches, and there has been much research progress on collaboration (e.g., Koschmann, Hall, & Miyake, 2002). On the other hand, learning is nearly always evaluated at the level of individual learning outcomes in assessing the effectiveness of systems and designs (e.g., Dillenbourg et al., 2001). For example, Scardamalia, Bereiter, and Lamon (1994) emphasized a public knowledge building discourse. Yet they provided only assessments such as reading levels and depth of explanation at the individual differences level. This choice is problematic because when a theory is contributed to the public discourse and the community works on it, the theory no longer belongs just to the student who contributed it. It belongs to all in the community who worked on it. Students' individual learning attainments are important; however, there is a need to examine how we can assess *collective aspects* of knowledge advances.

#### ***Assessment of Content and Process.***

Constructivist epistemology says that knowledge is constructed. If we want to prepare students for future learning—with less dependence on a teacher—we need to teach them to execute, monitor, and regulate the knowledge construction process. This would suggest that we must value not only what academic content is learned, but also how students achieve the learning. In higher education, there may be some emphasis on constructivist teaching and learning using asynchronous networked environments, but when assessment is carried out, primarily discrete knowledge and skills are considered. Even in more sophisticated environments involving peer learning, when group process is assessed, the assessment tends to focus on superficial features, such as whether students are contributing "equally" to the group work. We submit that assessment should tap both *collaborative process* and *knowledge products*.

### **Assessment of Knowledge Building and Portfolios**

This study aims to examine the roles of student-directed portfolio assessment in characterizing and scaffolding collaboration and understanding. In the CSCL literature, there are several examples of student-directed

assessment: self and peer-assessment in the SMART Environment (Vye, Schwartz, Bransford, Barron, Zech (1998), and reflective thinking in Thinker Tools (White, Shimoda, & Fredericksen, 1999). In our earlier studies, we have examined the use of student-directed portfolio assessments to characterize and foster knowledge building. We first designed knowledge-building principles and electronic portfolios for a graduate class (van Aalst & Chan, 2001) and further refined the designs in a Grade 12 classroom using communal portfolios (Chan & van Aalst, 2003). Students were asked to identify exemplary clusters of notes of their own and the class' best work and write a rise-above portfolio note referencing these notes and explaining the selection. We also examined individual knowledge advances using the notion of *depth of explanation* (Hakkarainen, Lipponen, & Jarvela, 2002). Students' participation in database usage (e.g., number of notes read, written, linked, revised) was assessed using server-log data with a programme called Analytic Toolkit developed by the Knowledge-Building Team (Burtis, 1998). Across different studies, we have found that portfolio scores were correlated with participation and conceptual understanding (Chan & van Aalst, 2003). Whereas portfolios commonly refer to individual's best work, we pioneered the notion of knowledge building portfolios for which students are asked to identify collective knowledge advances documenting the community's best work and progress.

The present paper continues this line of inquiry addressing the problem of assessing individual and collective knowledge advances in evaluating knowledge building. There are several refinements in our design: *First*, the earlier studies were conducted with graduate students and Grade 12 students in small classes. We want to examine, here, whether electronic portfolios can be extended to younger students in larger classes, thus exploring its value as a teacher assessment approach. *Second*, we earlier used four knowledge building principles for note selection; we now extend the use of knowledge building principles as scaffolds for student note writing as well as note selection. In particular, we ask students to write an essay on the basis of the portfolios thus investigating the relations between collaborative process and knowledge products. *Third*, our earlier studies included several components in the learning environment, and portfolio assessment was only one of them. Although it is typical of studies in technologically rich classrooms, the roles of knowledge-building principles and portfolios have not been specifically examined. In particular, it is not clear whether it is the portfolio task itself or the task augmented with the use of knowledge building principles that brought about the positive effects. This paper describes our refined design for knowledge-building portfolios. As well, we examine specifically several classrooms using Knowledge Forum (KF) only, KF with portfolios, and KF with portfolios guided by knowledge-building principles. While we recognize the complexity of classroom conditions, the comparison may help to illuminate the roles of knowledge building principles and portfolios.

In sum, the goal is to examine a knowledge-building environment using portfolio assessments for characterizing and assessing collaboration and conceptual understanding. There are several objectives: (1) To examine whether students using portfolio assessments with knowledge building principles showed more participation, deeper inquiry and conceptual understanding compared to their counterparts, (2) To examine different ways to assess knowledge building and investigate whether knowledge building inquiry and discourse are related to students' conceptual understanding, and (3) To examine how knowledge building principles and portfolios characterize and scaffold collective knowledge advances.

## METHOD AND DESIGN

### Participants

The participants were 119 students studying in four grade-nine Geography classes in a regular high school in Hong Kong, taught by the same teacher. Three of the classes were engaged in knowledge building using Knowledge Forum with different conditions. The fourth one was a comparison class that was not using KF; students in this class were required to submit a paper and pencil portfolio. The students at this school had high average abilities, they studied from English textbooks, and wrote in English on KF. Students were taught by an experienced geography teacher with over 12 years of teaching experience; he also had several years of experience using knowledge building pedagogy and Knowledge Forum.

### The Classroom Setting

Knowledge Forum was implemented in the geography curriculum starting in the second semester for a period of three months. The teacher integrated knowledge building pedagogy with the school curriculum. A number of curriculum units were taught including "Ocean in Trouble", "Rich and Poor," and "Saving our Rainforests". Students were asked to discuss the topics on Knowledge Forum after school, and problems emerging in the computer discourse were discussed in class. Students in the comparison class also worked after school because they needed to submit a paper-and-pencil portfolio.

## Design of the Learning Environment

The course was organized and informed by the knowledge-building pedagogy; students worked on Knowledge Forum as they generated questions, posed alternative theories and hypotheses, brought in new information, considered different students' views, and reconstructed their own understanding. Knowledge Forum was not used as an addition of computer software to the classroom activities; instead the knowledge-building principles and the work with Knowledge Forum were integrated with classroom instruction.

### *Developing a Collaborative Classroom Culture*

Before the implementation of Knowledge Forum, students were provided with learning experiences acculturating them into the practices of collaborative learning. Such learning experiences are particularly important for Asian students who are generally more used to a didactic mode of teaching. Several group learning activities were included, for example, jigsaw learning and collaborative concept mapping.

### *Introduction to Knowledge Building and Knowledge Forum*

Knowledge building was implemented in the three classes in early February. The teacher created a view called 'World Problems and How to look after the World' that was used as the focal problem. Three sub-views were included: 'Rich and Poor', 'World Oceans', and 'Tropical Rainforests' that link up the fragmented topics of the textbooks to allow for sustained inquiry. Typically the teacher wrote an introduction that explains the purposes of each view. As with other knowledge-building classrooms, students posed questions and problems; they made conjectures, examined different explanations, revised their 'theories' as they examined each other's KF notes.

### *Deepening Knowledge Building Discourse and View Management*

As the number of notes increased with time, teachers worked with students and identified sub-themes and created *rise-above* views. Clusters of notes were grouped, and key issues highlighted with the class. Students were also asked to pose 'rise-above' notes. View maintenance and continuous updating of views in the database made it easier for the community to identify the focus and themes of notes. Student could see more easily what was current in the views and focus their reading and writing.

### *Embedded and Concurrent Assessment Using Knowledge Building Portfolios*

After the introduction of Knowledge Forum and some initial work, there were differences in instruction: Whereas students in the 'KF class' continued to engage in KF discussion only, students in 'KF with portfolios class' were required to submit an electronic portfolio with a selection and explanation of four clusters of good discussion notes in the database. Students in 'KF with knowledge-building portfolios class' also needed to do this task, but they were provided with a set of knowledge-building principles as scaffolds in note writing and note selection (Table 1). Based on Scardamalia's set of knowledge-building principles, we have developed a smaller set designed for use as pedagogical and assessment tools. We adapted the guidelines from earlier studies, so they could be more accessible to middle-school students.

A brief description is given for the knowledge-building principles (for details, see Chan & van Aalst (2003): (1) *Working at the cutting edge*. This principle is related to epistemic agency, and it is based on the idea that a scholarly community works to advance its collective knowledge. For example, scientists do not work on problems of only personal interest, but on problems that can contribute something new to a field. (2) *Progressive problem solving*. The basic idea is that when an expert understands a problem at one level, he or she reinvests learning resources into new learning. In the scholarly community, we often find one study raises new questions that are explored in follow-up studies. (3) *Collaborative effort*. This principle focuses on the importance of working on shared goals and values in developing community knowledge. (4) *Monitoring personal knowledge*. This principle is based on the idea that metacognitive understanding is needed for knowledge-building work. Specifically, it requires students to have insight into their own learning processes. It is similar to progressive problem solving in that it documents the history of ideas or problems--but now the focus is placed on metacognitive processes. (5) *Constructive uses of authoritative sources*. This principle focuses on the importance of keeping in touch with the present state and growing edge of knowledge in the field. To make knowledge advancement requires making references, building on, as well as critiquing authoritative sources of information.

## Data Sources

### *Analytic Toolkit and Database Usage*

The Analytic Toolkit (ATK, Burtis, 1998) provided an overview of student participation using information on database usage. Several quantitative indices include: (a) Number of notes *written*, (b) Number of notes *read*, (c) Number of *scaffolds* used; scaffolds are thinking prompts (e.g., I need to understand) to guide writing and

collaboration, (d) Number of notes *revised*; revision is an important metacognitive process; (e) Percentage of notes *linked* to other notes, and (f) Percentage of notes with *keywords* that can help others to search the notes.

Table 1. Teacher Guidelines on Knowledge Building Principles and Portfolios

<b>You need to select four best clusters of notes together with a summary note that explains why you have selected the notes. Use the principles and criteria to help you with note selection.</b>
<b>Principle One: Working at the Cutting Edge</b> <ul style="list-style-type: none"> <li>Identify knowledge gaps, inconsistencies and ask productive questions</li> <li>Pose problems that extend the edge of understanding of the community</li> <li>Pose problems with potential for continual discussion and inquiry (i.e., interest many people)</li> </ul>
<b>Principle Two: Progressive problem solving</b> <ul style="list-style-type: none"> <li>Show continual efforts to grapple with problems posed by classmates</li> <li>Pose notes aimed at addressing the original problem and questions arising from them</li> <li>Show sustained inquiry: Identify the problem, solve the problem, but keep asking new questions</li> <li>Reinvest efforts to keep solving new problems to improve ideas</li> </ul>
<b>Principle Three: Collaborative Effort</b> <ul style="list-style-type: none"> <li>Use various KF functions such as references and rise-above to make knowledge accessible</li> <li>Summarize different ideas and viewpoints and put them together as a better theory</li> <li>Help classmates to extend and improve their understanding</li> <li>Encourage classmates to write notes that follow the other principles</li> </ul>
<b>Principle Four: Monitoring Own Understanding</b> <ul style="list-style-type: none"> <li>Explain what you did not know and what you have learned</li> <li>Recognize discrepancies and misconceptions and new insights; trace own paths of understanding</li> <li>Show your new ways of looking at things (questions, ideas, issues) after examining other KF notes</li> </ul>
<b>Principle Five: Constructive Uses of Different Sources of Information</b> <ul style="list-style-type: none"> <li>Use information from other sources ( Internet, newspaper...etc) to support or explain your ideas</li> <li>Bring together classroom learning, information from textbook, classmates' KF notes</li> <li>Provide contrasting or conflicting information to what is printed in the textbook</li> </ul>

#### *Depth of Inquiry and Depth of Explanation*

Computer notes consisting of responses and questions were examined for assessing knowledge-seeking inquiry, based on earlier research on depth of explanation (Hakkarainen et al., 2002). Students' responses were coded on a 7-point scale to distinguish the levels of depth of inquiry, and students' questions were coded on a 4-point scale (Chan & van Aalst, 2003). These levels ranged from fragmented responses to paraphrasing information to inferences to explanatory inquiry.

#### *Knowledge Building Portfolios*

Students were asked to prepare a portfolio of four clusters of notes in which they provided evidence for knowledge-building principles (i.e., cutting edge, progressive problem solving, collaborative effort, monitoring own knowledge, constructive uses of resources). In their selection, they needed to include their own notes as well as others' notes in the database. They also needed to write an explanatory statement for each cluster on why these notes best demonstrated evidence of knowledge building. Portfolios were coded on both explanation and evidence of knowledge building on a 6-point scale.

#### *Conceptual Understanding*

To assess students' conceptual understanding of the domain in question, students in all classrooms were administered the following writing task: "*We have been exploring three major world problems, namely 'Rich and Poor', 'Ocean in Trouble', and 'Deforestation'. In not less than 300 words, express your view on the following question: Who and how should we look after the World?*" Students' responses to the writing task were coded using rubrics and schemes regularly used in the school.

## RESULTS

### Class differences on participation, collaboration and conceptual understanding

#### *Participation and Collaboration Shown on Database Usage*

We first examined students' overall participation and collaboration based on database usage on Knowledge Forum. The general descriptive picture from Analytic Toolkit indicated a sizeable usage of the databases: There were totals of 661, 302, and 1090 written notes, respectively, contributed by the three classes (KF, KF with portfolio, and KF with knowledge-building portfolio). The average number of notes written were 16, 8, and 27 for the three conditions, respectively, in a 3-month period. To simplify presentation, the ATK indices were combined using factor analyses: Factor One called *ATK Knowledge Building Inquiry Index* (i.e., write, read, scaffold) explained 42.6% of the variance, and Factor II called *ATK Knowledge Building Visual Organization Index* (i.e., keyword, link) explained 10.1% of the variance. ANCOVA analyses controlling for differences in academic achievements showed that students in different design conditions had different participation scores,  $F(2, 113) = 7.31, p < .001$ . Table 2 shows that KF class with kb portfolios had a higher ATK Inquiry index than Knowledge Forum (KF) class, and KF class with portfolios scored higher on Inquiry Index than KF class. There were no significant differences for the Visual Organization index.

#### *Depth of Inquiry and Depth of Explanation*

The entire set of computer notes including questions and responses were scored. An overall weighted score called *Depth of Inquiry* was computed based on quality and frequency of questions. ANCOVA analyses controlling for differences in academic achievements showed that KF with kb portfolios class had significantly higher mean scores than the other two classes,  $F(2, 113) = 9.23, p < .001$  (Table 2). Students' written responses were also scored and computed to obtain an overall weighted score called *Depth of Explanation*. ANCOVA showed that KF with kb portfolio class had a significantly higher mean score than KF with portfolio class,  $F = 3.98, p = .021$  (Table 2). These results suggest that students scaffolded with knowledge building principles and portfolios participated more, and they produced deeper questions and explanations.

#### *Conceptual Understanding*

The means of conceptual understanding scores based on a writing task were 5.5 for no KF class, 5.2 for KF class, 5.2 for KF class with portfolios, and 7.0 for KF class with knowledge-building portfolios. ANCOVA analyses indicated that significant differences were obtained favoring KF with knowledge-building portfolios over other classes,  $F=6.6, p < .001$ .

Table 2. Scores on Participation, Inquiry, and Explanation Across Design Conditions

Class	KF		KF with Portfolio		KF with portfolio and principles	
	M	SD	M	SD	M	SD
ATK Inquiry	-.45 b	.37	.03 a, b	.83	.44 a	1.2
ATK Visual Organization	-.17	.82	.01	.96	.18	.92
Depth of Inquiry	1.85 a	1.34	2.24 b	1.33	3.59 a, b	1.6
Depth of Explanation	3.55	1.21	3.01 a	1.25	4.33 a	2.15

Note: Means in a row sharing subscripts are significantly different.  $p < .01$ .

### Relations among Participation, Inquiry and Conceptual Understanding

We examined the relations between students' ATK participation and depth of inquiry with their conceptual understanding for all students working on KF. We used students' scores on Hong Kong Attainment Tests as covariates, controlling for the effects of academic achievement. Participation was measured by ATK with the two factors of Inquiry and Visual Organization. Depth of inquiry was assessed by students' weighted scores on questions and responses. Correlation coefficients show that ATK Inquiry Index, was significantly correlated with Depth of Inquiry ( $r = .39, p < .001$ ), Depth of Explanation ( $r = .35, p < .001$ ) and writing ( $r = .16, p < .05$ ). ATK Visual Organization Index was significantly correlated with the Depth of Inquiry ( $r = .48, p < .001$ ) and Depth of

Explanation ( $r = .27, p < .05$ ). Both inquiry and explanation scores were correlated with writing ( $r = .20, p < .01$ ). These findings show that participation on KF and depth of inquiry were related to conceptual understanding.

Table 3. Correlations among Participation, Inquiry and Conceptual Understanding

	ATK inquiry	ATK visual organization	Depth of inquiry	Depth of explanation
ATK visual	.52***			
Depth of inquiry	.39***	.48***		
Depth of explanation	.35***	.27**	.27**	
Writing	.16*	.02	.20**	.20**

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

### Relations among Participation, Inquiry, KB Portfolios and Conceptual Understanding

We also examined the relations between students' knowledge building portfolio scores with other measures for the KF with kb portfolio class ( $n=29$ ). We used scores on Hong Kong Attainment Tests as covariates controlling for the effects of academic achievements. The knowledge building portfolios were rated on a 6-point scale both on the explanatory statements and the selection of notes. Knowledge building portfolio ratings were significantly correlated with ATK Inquiry ( $r=.35, p=.08$ ). As well, knowledge building portfolio ratings were significantly correlated with essay writing reflecting conceptual understanding ( $r=.37, p=.066$ ), both at .10 level. Students showing more evidence of knowledge building in their portfolios scored higher on conceptual understanding.

### Characterizing Individual and Collective Knowledge Advances

Students were asked to produce four clusters of notes with explanations in their portfolios. Two examples are provided here to illustrate the differences of portfolios with and without principles. As well, the portfolio note guided by knowledge-building principles helps to characterize individual and collective knowledge advances.

Figure 1. A portfolio note illustrating a knowledge-building principle and collective knowledge advances

**The Theme of the Discussion** The effects of chemicals on the oceans..... It began with the question "Do shipwrecks [such as] the Titanic add pollution to the world' s oceans?" **My Interpretation** At first, I thought that my question was quite debatable<sup>1</sup>. But in the end, I still thought that shipwrecks weren't as harmful as they seemed to be. I thought that after decomposition of oil spills, the oceans could return to their initial form, but this idea was heavily criticized by my classmates. They all thought that shipwrecks brought serious threats to the oceans<sup>2,3</sup>. ...They said that if oil was spilt into the oceans, it could kill many animals before the oil could be decomposed. Mr. Lee told us that if a certain species is killed, it might break the food chain. Therefore, oil spills are quite dangerous to our oceans. **I was [shown] that oil spills were far more serious than I ever expected.** Then, CW corrected a stupid mistake that was made by me. He told me that the Titanic ran on coal, not on oil. Therefore, I realized that I actually had a problem with my question. **Then, the first evolution came. ER suddenly asked if the oil from an oil spill is an ocean resource<sup>4</sup>.** Naturally, CW answered this question<sup>5</sup>. **Here's the second evolution. CY started to argue that tankers carrying chemicals are more dangerous than oil tankers<sup>6</sup>,** CW and I didn't agree though<sup>7</sup>. We thought that although cyanide is more poisonous than oil, cyanide is soluble in water. Therefore, its effects on the oceans are less than those of oil<sup>8</sup>. WY agreed with this<sup>9</sup>, SL too. He said that oil is difficult to clean up, and could kill heaps of wildlife, **but I still had my questions...** **Are oil spills really that bad to the oceans?** After 50 years or so, the oil would start to decompose and the corals would grow on the shipwreck, it' d become an artificial reef, what' s the problem with that<sup>10</sup>? CW agreed with me that shipwrecks aren't really that bad in the long term "water wave will wash the oil and make them into smaller particles and decompose them in the following years!"<sup>11</sup> **TY also pointed out that pollution is proportional. Oil spills could help the environment-- "the resources used up " and the curve of the pollution is proportional. So if we can control the use the resources , we can also reduce the level of pollution ~"**<sup>12</sup>  
**Principle 2 Improvable Ideas/Progressive Problem Solving** I [think] that this is a principle 2 note because in this cluster of notes, many new and improved questions have evolved from one simple note in the beginning. **Reasons** In the beginning, I was asking about shipwrecks, soon the discussion turned to chemicals and finally a new concept was pointed out (pollution is proportional). Every time there was a question, we'd solve it, think of another question and solve that as [we] get better answers and more questions.

Note: The number in superscripts are computer notes in the databases included as reference notes

Figure 1 shows an example illustrating how portfolios might help to identify and characterize knowledge-building episodes in the community, and how they scaffold the student's reflection and understanding. At the beginning, Student A referred to a question he had posed, 'Do shipwrecks add pollution to the world's oceans ?' Instead of asking a typical textbook question, Student A posed what might be called an authentic problem with potential for inquiry (Scardamalia, 2002). Student A identified diverse ideas from his classmates and explained how they differed from his views. In examining the discourse, Student A also became more aware of the 'mistakes' (misconceptions) he had (Titanic used coal not oil). The portfolio note illustrated how the students worked collaboratively on the problem, pushing for new understanding, rather than having premature closure.

As they pursued the problem, Student A wrote that he had the 'first evolution' [insight] when someone asked whether an oil spill can be a resource. He then described another evolution when the classmates discussed whether oil spills or chemical pollutions are more serious. Further inquiry of the problem led to improved ideas and new realizations – proportionality and control of resources as ways to control pollution. The portfolio note helps demonstrate that knowledge building involves a problem-centred collaborative inquiry process where new ideas are examined, debated, and improved upon. As the student explained, "At first, I was asking about shipwrecks, soon the discussion turned to chemicals and finally a new concept was pointed out (pollution is proportional). Every time there was a question, we'd solve it, think of another question and solve that as well to get better answers and more questions."

Figure 2. An example of a portfolio without knowledge-building principles showing shallow discourse

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*This topic is ocean in trouble. The question is "Oil spill is a kind of pollution. But where does it come from? From an accident of a ship or from nature?"<sup>1</sup> This is a simple question, I don't think nature can make oil spill occur.<sup>2,3,4</sup> **These three notes have answered the big question of oil spill.** Oil [comes] from the ground and [it is] transported by ship. But some accidents have happened [and] the oil spills on the surface of ocean. Oil spill is a serious problem of pollution; it kill[s] the marine wildlife and make[s] the world problem [creating] lack of fishes. The other most interesting note comes from "Why a small amount of oil will be formed when it is raining?"<sup>5</sup> Before I see this note, I don't know the rain contains oil, I think this is silly to say "Oil Rain!". There are three answer[s] to the notes, that include: "Internet says that the rain may contain a small amount of oil."<sup>6</sup> ", the car fumes contain some toxic chemicals, and a little amount of oil may still be in the smoke. So, the smoke goes up and [gets into] the rain. "<sup>7</sup> and "the soil is fat and may contain oil, so when rainwater come through, oil may [be] flushed away with the rainwater..."<sup>8</sup> **I think the acceptable answer is [that] smoke with water vapour is absorbed by the Sun, and [it]condenses to from cloud [and] finally forms rain.***

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Note: The number in superscripts are computer notes in the databases included as reference notes

We provided an example of a different kind of note when students also found exemplary notes from the class on the same theme without having been given the scaffolds of the knowledge-building principles. In this example, the selection of question is different: Student B identified a note that asked quite a general question - where does an oil spill come from? He then wrote he found three notes that answered the question and the problem was considered solved. The same situation occurred again – This time the question was more interesting but Student B still used the strategy of finding three notes that answered the question and found the most acceptable one. The notion of improvable idea or collective advances cannot be found in this note. Instead the student seemed to be more engaged in a form of premature closure focusing on finding the correct answers.

## DISCUSSION

We have described a knowledge-building environment augmented with the use of portfolios and knowledge-building principles to characterize and scaffold collaborative inquiry. Primarily we turned over agency to students, asking them to assess their own and the community's knowledge advances in the computer discourse, using an electronic portfolio. We extended our earlier work from graduate students and senior-secondary students to middle-school students in large classes. We used knowledge building principles more intensively as both note writing and note selection guidelines. The findings show that students provided with knowledge-building principles as scaffolds participated more and engaged in deeper inquiry. Consistent with our earlier work (Chan & van Aalst, 2003), knowledge building activity was related to students' conceptual understanding.

### Knowledge Building Portfolios as Scaffolds for Collaborative Inquiry

We first examine the roles of knowledge-building principles and portfolios and consider how they may scaffold collaborative inquiry. In this study, we had several design conditions. The results showed that student provided with knowledge-building principles participated more and engaged in deeper inquiry than their counterparts. A system of knowledge-building principles was postulated by Scardamalia (2002) for theorizing the dynamics and



processes of knowledge building. Thus far, researchers used the framework of knowledge building principles to analyze the databases. We adapted the principles and turned over to students the responsibility for identifying knowledge-building episodes in their computer discourse. In doing that, knowledge-building principles become not just analysis tools, but pedagogical and assessment tools for scaffolding knowledge building. We propose that when students work on identifying knowledge building episodes, the principles can be a form of scaffold that helps them recognize what constitutes productive discourse. As they see different models, they would be able to move towards producing better notes and engaging in deeper discourse. Protocol examples indicated that Student A was able to use the principle 'progressive problem solving' to explain how ideas evolved and improved over time. By contrast, Student B was merely identifying good answers to questions classmates posed. Without knowledge-building principles or other criteria, students could easily see collaboration as discussion and producing good answers. That may explain why many students are reluctant to participate in discussion on networked environments. Knowledge building principles as scaffolds may help students understand what constitutes progressive discourse. As the goal of knowledge building is improvable ideas (Scardamalia & Bereiter, 2002), we made that explicit to students; then that could become a goal of the community.

### **Alignment of Learning, Assessment and Collaboration**

We have designed an environment that was intended to address certain gaps for designing assessment in CSCL classrooms. Earlier, we noted three of these issues: Assessment of learning versus assessment for learning, assessment of individual and collective advances, and assessment of processes and content. *First*, the knowledge building portfolios play dual roles of characterizing and fostering collaboration. Commonly, assessment is concerned with analyzing the collaborative process or evaluating what students have learned. Knowledge-building portfolio assessment is designed so that self- and peer-assessments foster inquiry and understanding. As shown above (Figure 1), in identifying exemplary clusters of notes and providing explanations, students must browse through the database and synthesize their own and collective understanding. Fragmented understanding, scattered discussion, and superficial work might be avoided. The assessment approach examines collaboration as well as provides a tool for deepening inquiry. *Second*, this study included several measures (e.g., ATK, depth of inquiry) to assess knowledge building. Specifically, we designed knowledge-building portfolios that capture both individual and collective aspects of knowledge building. As shown in the portfolio example (Figure 1), the student was not merely describing his personal work; he was describing how a problem was addressed by a group of students, what views they held, what misconceptions were identified, what critical incidents took place, and how the idea was gradually improved. Knowledge building postulated by Bereiter and Scardamalia (2002) is analogous to scientific inquiry in scholarly and scientific communities. Even middle-school students can be engaged in a process similar to the writing of scholarly reviews when someone integrates differing ideas/studies to provide the 'state of knowledge' for a certain problem/theme. Knowledge-building portfolios capture both collective knowledge advances as well as students' growth in understanding. *Third*, the portfolios showed that content and process were both assessed. The portfolio example illustrated how students were engaged in progressive problem solving (see Figure 1); it also provided rich information about how they have gained subject-matter knowledge (e.g., oil spills as resources, proportionality, control of resources).

It may be useful to note the limitations of this study. Due to the complexity of classroom life, comparison of design conditions across classrooms necessarily faces many problems common in technology studies. Whereas the quantitative findings are included, caution needs to be exercised in interpreting them. These different design conditions, however, help us to understand more fully how knowledge building works. We also emphasize examining portfolios can help characterize and assess both individual and collective understanding. Ongoing analyses and inter-rater reliability are being conducted. In terms of pedagogical implications, earlier we noted problems and challenges of low and variable participation rates and problems with teacher assessment. The portfolio approach may be a way to address the problems, in that students need to write some notes before they can have enough notes to do the portfolios. Or at least they would need to do substantial reading of others' notes when putting together the portfolios. We also noted the problems of teachers having difficulties with reading hundreds or even thousands of notes. The two-pronged approach of Analytic Toolkit providing an overview as well as the portfolios--a synthesis of what goes on in computer discourse-- can help teachers recognize and assess overall participation as well as critical incidents of knowledge building in the community. They would be able to identify areas where students may have problems and what progress they have made.

In sum, we have extended our earlier work examining portfolio assessments and demonstrated more clearly the roles of knowledge building principles. We propose that when students are provided with the principles, they can become more aware of what productive discourse entails; the principles are scaffolds for their knowledge-building progressive inquiry. As well, students are not merely focused on their own work, they are engaged in characterizing the community's best work and progress. Our approach of making knowledge building explicit to students is consistent with current emphasis on alignment of learning with assessment (e.g., Shepard, 2000). We

have extended the idea of portfolio as assessing individual to community progress and demonstrated how knowledge-building portfolios may characterize and scaffold collective knowledge advances.

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