Fostering Knowledge Building Using Concurrent, Embedded and Transformative Assessment for High- and Low-Achieving Students

Carol K.K. Chan and Eddy Y. C. Lee

The Faculty of Education, The University of Hong Kong, Pokfulam, Hong Kong, China
ckkchan@hkucc.hku.hk, eddy.yclee@gmail.com

Abstract: We describe the design of a knowledge-building environment and examine the roles of knowledge building principles and portfolios as scaffolds in fostering collaboration for students of different achievement levels. Students assessed their contribution in Knowledge Forum™ using rubrics and they wrote electronic portfolios and group reviews to assess both individual and community progress. We used a 2 x 2 design (knowledge-building principles x achievement) with four classes of 9th grade students (n = 141) working on Knowledge Forum. We obtained the following results: (1) Students scaffolded with knowledge-building principles showed more participation and conceptual understanding than students working on Knowledge Forum with no principles; the effects were more pronounced for low-achievers compared to high-achievers, (2) Students' portfolio scores predicted domain understanding over and above the effects of academic achievement, and (3) Analyses of knowledge-building discourse and portfolios showed how students made progress in their collective knowledge advances.

Keywords: knowledge building, collaborative inquiry, assessment, electronic portfolio.

Introduction

There is now much interest in examining collaborative inquiry and specifically how computer-mediated discourse can promote learning and understanding (Koschmann, Hall, & Miyake, 2002). With major shifts from individual towards social views of learning (Paavola, Lipponen & Hakkarainen, 2004; Sfard, 1998), Bereiter and Scardamalia proposed that schools and classrooms should be re-structured to foster a social process of progressive knowledge building guided by the 'Knowledge-Building Community' Model (Bereiter, 2002; Scardamalia & Bereiter, 2006). The theoretical ideas of this model, namely, 'intentional learning' (Bereiter & Scardamalia, 1996), 'the process of expertise' (Bereiter & Scardamalia, 1993) and 'schools as knowledge-building communities' (Bereiter & Scardamalia, 1996) are mediated in a computer learning environment called Knowledge Forum™ (Scardamalia & Bereiter, 1994). Students pose questions, theories and explanations, and use graphics in the computer database as they engage in collaborative problem-centred inquiry. The epistemology of Knowledge Building, supported by the software, Knowledge Forum, aims at helping students view knowledge as an object of inquiry, and improving the knowledge of the community. Scardamalia (2002) has postulated a set of knowledge building principles for characterizing the dynamics of knowledge building emphasizing the need for students to pursue and improve ideas for collective advances as in a research community.

Decades of research have shown the roles of knowledge building in advancing student understanding (e.g., Hakkarainen, 2003; Scardamalia, Bereiter & Lamon, 1994; Zhang et al., in press). Although there has been much progress, there continue to be major challenges to the recognition and assessment of collective knowledge building, a major theoretical issue in research on computer-supported collaborative learning (CSCL) and a key pedagogical issue for teachers implementing knowledge building. In addition, there is a general belief that knowledge building and related sorts of high-level learning goals of metacognition and epistemic agency are only attainable by high achievers rather than the mediocre and low-achieving learners. Such beliefs persist despite research indicating the role of higher-order thinking for low-achieving students (e.g., Zohar & Dori, 2003) and they form barriers to teachers engaging in knowledge building in their classrooms. We need to examine how knowledge building can be assessed in classrooms and how assessments can be used to guide improvements in knowledge building. We are particularly interested in examining the notion of concurrent, embedded and transformative assessment (Scardamalia, 2002), emphasizing students' *epistemic agency* in assessing their own and community progress. We believe that student assessing their own knowledge building can take epistemic agency to a high form, thus serving the dual roles of assessing and fostering collaboration. We also sought to examine if collective knowledge building focusing on community progress might be relevant for students of diverse backgrounds.

We continue with our ongoing research program proposing that "assessment" in CSCL should serve the dual roles of characterizing and fostering knowledge building, and that students can play major roles in assessing their *collective* understanding (Lee, Chan & van Aalst, 2006; van Aalst & Chan, 2007). Due to epistemological changes and new understandings about learning, the form, content and use of assessment should aim at understanding stemming from the student's point of view (Shepard, 2000). Since knowledge construction is an ongoing process, evidence of learning, should, therefore, be provided by learners themselves based on knowledge-advancement criteria. In our earlier studies we have examined the characterization and fostering of knowledge building through the use of e-portfolio in Knowledge Forum -- Students were asked to identify clusters of notes that best illustrate knowledge building episodes guided by some principles; we found these knowledge-building portfolios could both characterize and foster knowledge building (Lee et al., 2006; van Aalst & Chan, 2007).

The present paper continues this line of inquiry addressing the problem of assessing individual and collective knowledge advances in fostering collaboration for students of different abilities. There are several refinements in our design. First we aimed to extend our work to see how knowledge building and reflective assessment could work for students of different achievement levels, thus addressing problems of barriers to implementing knowledge building in classrooms. We included students with different achievement groupings to examine more clearly how knowledge-building pedagogy might influence students of different backgrounds. Second, we used reflective assessment more intensively -- In the previous studies students were asked to produce electronic portfolios documenting high points in knowledge building. In this study, from the start, students were engaged in using depth of inquiry and explanation *rubrics;* they were asked to produce both portfolios and group review journals to capture the best knowledge-building incidents, thus exploring both *individual* and *community* progress more deeply. Third, we tracked more closely student growth and knowledge advances in the community through analyzing a major inquiry thread in student discourse.

This paper describes our continuing work in exploring and refining the design of student-directed assessment in characterizing and fostering collaboration. We investigated specifically several Knowledge Forum classrooms examining students assessing their own discourse with or without knowledge-building principles. Building on earlier work, we expected that using peer assessment and making assessment criteria explicit would help students engage in more knowledge building and domain understanding. We also examined whether knowledge-building portfolio assessments could also work for students of different abilities. There were several objectives: (1) To examine if students using knowledge-building principles in writing notes and portfolios showed more participation and conceptual understanding compared to their counterparts, and to examine such effects on students with different achievement levels, (2) To examine the roles of knowledge-building and portfolios on domain understanding, and (3) To investigate growth in the community and to examine how knowledge building principles can characterize and scaffold collective knowledge advances.

Method

Participants

The participants were 141 students studying in four grade-nine Geography classes in a regular high school in Hong Kong. The students at this school studied from English textbooks and wrote in English in Knowledge Forum. The students were taught by an experienced geography teacher with over 15 years of teaching experience; he also had several years of experience using Knowledge Forum. The teacher taught all 4 classes. Students in Grade 9 were streamed into different classes by academic achievement based on school examination results. This study used a 2 x 2 design (knowledge-building principles x achievement); the four classes all used Knowledge Forum and they included (a) High-Achieving with Knowledge-Building Principles, (b) High-Achieving with no Knowledge-Building Principles, (c) Low-Achieving with Knowledge-Building Principles and (d) Low-Achieving with no Knowledge-Building Principles.

Design of the Learning Environment

Knowledge Forum was implemented in the geography curriculum in the second semester of the year (Feb-May). The teacher integrated knowledge-building pedagogy with the school curriculum; several curriculum units were taught including "Oceans in Trouble: Scarcity and Economic Development", "Rich and Poor: Poverty and Economic Development", "Saving Our Rainforest: Sustainability and Economic Development". Teachers conducted class discussion during school and students were asked to deepen their understanding of the course materials through the use of KF after school. We briefly describe the design of the knowledge-building environment:

1. Cultivating a Collaborative Culture. Before the implementation of Knowledge Forum, all students were provided with learning experiences to familiarize them with collaborative learning. Such learning experiences are particularly important for Asian students who are more used to the didactic mode of teaching. Several group learning activities were included, for example, group discussion, jigsaw and collaborative concept mapping.

2. Developing knowledge-building inquiry on Knowledge Forum. Knowledge Forum was implemented formally in the four classes in February. The teacher constructed the "Welcome View" with different topics for discussion and a view on assessment which had two sub-views, "Group Review Journal" and "Portfolio" (A view is a discussion area). The teacher designed the Knowledge Forum views to promote knowledge building while aligning the topics with the school curriculum. 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 understandings. Problems emerging from the computer discourse were discussed in class.

3. *Deepening knowledge building discourse, view management and rubrics*. It is common that forum discussion tends to be scattered and fragmented so students need to be scaffolded to deepen their inquiry. Over time, the teacher worked with students and identified several sub-themes, note clusters, and questions that needed further inquiry. Clusters of notes were moved into "rise-above" views to help focus the discussion. Several weeks after beginning their work on Knowledge Forum, students were taught how to assess their own notes with the *rubrics* for depth of inquiry and explanation to help them write better notes.

4. ***Portfolio Assessment and knowledge building principles.*** For concurrent, embedded and transformative assessments, students were required to work in groups to complete an electronic "Group Review Journal" in which they had to evaluate the quality of the online discourse of their classmates in one of the "view" on Knowledge Forum. Also, each student was required to produce an electronic portfolio consisting of several best clusters of notes. For both group reviews and portfolios, students in two classes were given a set of principles as criteria for writing and assessing their notes whereas the other two classes just selected notes on their own. The teacher instruction for the knowledge-building portfolio was as follows (see Lee et al., 2006):

> You have to select four best notes together with a summary note that explains why and how you have selected these notes. Use the 'references' and 'scaffolds' and 'note reader' to write notes and complete the portfolio. One note is defined as a cluster of notes. The four notes selected will include notes posed by yourself as well as your classmates. You need to write a summary for each selected note. The summary note should explain the reasons for choosing that particular cluster. You need to organize the notes to help the readers understand the selected work, for example, give a theme of the selected notes and state which principle(s) can be identified. Use the guide on knowledge-building principles to help you with note writing and note selection.

Students were asked to submit the portfolio guided with a set of knowledge-building principles. A brief description is given of these principles adapted from Scardamalia's more complex system (see van Aalst & Chan, 2007): (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 only of personal interest, but on problems that can contribute something new to a field. (2) *Progressive problem solving/Ideas Improvement*. 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/Community knowledge.* This principle focuses on the importance of working on shared goals and values in developing community knowledge. (4) *Monitoring personal knowledge/epistemic agency.* 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 using and critiquing authoritative sources of information.

Data Sources

Analytic toolkit and database participation

The Analytic Toolkit (Burtis, 1998), a software designed by The Knowledge Building Research Team at The University of Toronto, provides 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., my theory, I need to understand) to guide writing and collaboration, (d) Words per note that might reflect quality of responses; (e) Percentage of notes *linked* to other notes, (f) Percentage of notes with *keywords* that can help others to search the notes, (g) Percentage of notes read and (h) Build-on trees indicating the number of notes in a discussion thread.

Depth of inquiry and depth of explanation

Computer notes on Knowledge Forum in a major inquiry thread were examined for depth of inquiry and explanation, based on cognitive research on problem-centred inquiry (Chan, Burtis & Bereiter, 1997) and an earlier study (Lee et al., 2006). 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. These levels ranged from fragmented responses to paraphrasing information to inferences to explanatory inquiry. Inter-rater reliability is currently being established.

Knowledge-Building Electronic Portfolios

Students were asked to produce an e- portfolio where they identified incidents of knowledge building in the discussion; some were provided with principles depending on the condition. Typically the portfolio consisted of 2 components – (1) students needed to identify a cluster of notes that illustrated knowledge building and (2) they needed to write a short explanatory statement explaining why the selected notes illustrated knowledge building. We employed the scheme of portfolios (Lee et al., 2006) in rating the portfolios with a 6-point scale. For inter-rater reliability, 35% of portfolios was scored by a second rater and the inter-rater reliability was 0.90.

Conceptual understanding

To assess students' conceptual understandings, students in all classrooms were administered this writing task: *'Discuss ONE of the following statements: (1) Marine pollution is mainly caused by overpopulation, and (2) The root of the world problems, such as poverty, overfishing, marine pollution and deforestation, is the use of technology.'* All the students' essays were scored with a 7-point scale used in school assessment.

Results

Differences on Participation, Collaboration & Conceptual Understanding across Classes

Participation on Knowledge Forum across Classes

Overall participation and thread length. We examined students' overall participation in Knowledge Forum using The Analytic Toolkit. The average numbers of notes written were 13.18, 12.95, 7.78, and 6.73 for classes of High-Achieving with Knowledge-Building principles, High-Achieving with no Knowledge-Building principles, Low-Achieving with Knowledge-Building principles, and Low-Achieving with no Knowledge-Building principles respectively. We also examined the *discussion threads* across classes. The ATK program generated four categories for size of thread – (i) small (2-5 notes), (ii) medium (6-20 notes), (iii) large (21-40 notes), and (iv) very large (>40 notes). The findings showed that the two kb principle classes had 75 small clusters, 40 medium clusters, 3 large threads and 1 very large thread (with 102 notes). The two no-knowledge-building principles classes had 69 small threads, 45 medium threads, and 1 large thread. The thread lengths suggest substantive interaction among students.

Participation in Knowledge Forum (ATK Indices). We examined student participation in Knowledge Forum based on several ATK indices including number of notes written, percentage of notes read, keywords, links, and revision. We first examined whether there were differences across classes for the whole period. A two-way MANOVA (principles x achievement) showed significant differences across classes, $F(8, 131) = 15.1$, $p < .001$. Univariate analyses showed that there were main effects for *knowledge-building principles* for the participation (ATK) indices of 'linked notes', $F = 4.36$, $p < .04$, 'No. of View Worked in', $F = 25.1$, $p < .001$, and 'Percentage Keywords', $F = 19.01$, $p < .001$ favoring students in the knowledge-building principles classes. We also obtained main effects for *achievement groupings* on the ATK participation indices of 'Scaffolds', $F = 7.64$, $p < 0.01$, 'Note Created', $F = 5.03$, $p > .03$, and 'Words per note', $F = 12.2$, $p < .01$ with high-achievers outperforming low-achievers.

Changes and Growth in Participation (ATK Indices). We examined whether there were increases over time in students' Knowledge Forum participation. We divided up the whole period of instruction into two roughly equal time intervals called Period 1 and Period 2 and computed the gain scores (Table 1). Two-Way (principles x achievement) MANOVA on gain scores showed overall significant differences, $F(8, 130) = 2.26$, $p < .05$. Univariate analyses showed that classes with knowledge-building principles had significantly higher *gain* scores than their counterparts on 'Keyword', F=10.1, p<.002, 'Notes Linked', F=8.15, p<.005, 'Scaffolds', F=7.96, p<.005, 'Views Worked', F=5.6, p<.002, and 'Words per note', F=4.74, p<.04. These results indicated that students in classes using knowledge building principle made more gains than their counterparts without the principles. As well, results indicated significant interaction effects (principles x achievement) for gains in 'Keyword', F=17.4, p<.001, 'Notes Linked', F=12.01, p<.001, 'Percentage of Notes Read', F = 11.72, p<.001, and ''Views Worked in", F= 8.4, p<.01. Examination of mean scores indicated that the gains for classes using knowledge-building principles over their counterparts were mainly present for Low-Achieving students using principles. There were no differences in gains of ATK participation indices for achievement groupings. These results suggest that the effects of knowledge-building principles on gains in ATK participation were found mainly among low-achieving students (Table 1)

Portfolio Scores and Domain Understanding Across Classes

Portfolio Ratings. Students obtained portfolios scores of 3.67, 3.16, 2.27 and 2.04 for classes of High-Achieving with Knowledge-Building principles, High-Achieving with no Knowledge-Building principles, Low-Achieving with Knowledge-Building principles, and Low-Achieving with no Knowledge-Building principles respectively. To make the differences more distinct, we grouped portfolio ratings into low-level and high-level portfolios for analyses. Two-way ANOVA showed marginally significant effects favoring knowledge-building principles classes, F = 3.75, p=.056. There were also main effects for achievement groupings, F= 19.4, p<.001 favoring high-achievers over low-achievers.

Table 1: Participation on Knowledge Forum for classes in period 1 and period 2.

		Words per note		No of Notes		No of Scaffolds		No of Views		No of Notes Read		% Linked Notes		% Keywords	
		P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Without Knowledge-Building Principles	Low Achieving	49	22.7	210	29	2.7	0.2	1.2	0.4	71.6	17.7	58	34	60	33
	High Achieving	55	92.3	361	161	8.7	5.5	1.4	1.5	175.7	114.3	65	65	44	46
With Knowledge Building Principles	Low Achieving	27	37.9	136	146	2.9	3.5	1.4	1.9	19.1	41.1	37	63	41	77
	High Achieving	45	164.9	320	202	6.0	5.9	1.6	1.6	99.3	74.3	57	51	55	47

*Domain Understanding***.** The means of conceptual understanding scores based on the writing task were 5.3, 5.4, 5.4, and 3.6 for High-Achieving with Knowledge-Building principles, High-Achieving with no Knowledge-Building principles, Low-Achieving with Knowledge-Building principles, and Low-Achieving with no Knowledge-Building principles respectively. To examine differences across classes, a two-way ANOVA (principles x achievement) was conducted on writing scores. Results indicated there were main effects of knowledge-building principles favoring classes with principles F(3, 135) = 10.2 p<.01. There were also main effects of achievement favoring High-Achieving classes F(3, 135) = 9.9 p<.01. In addition, there was an interaction effect of principles x achievement, F(3, 135) = 10.6 p<.0.01 indicating the effects of the principles were more pronounced for Low-Achieving students using Knowledge-Building principles.

Relationships among Participation, Portfolios and Domain Understanding

We examined the relations between students' ATK participation with their conceptual understanding for all students working on Knowledge Forum. Participation was measured by ATK measures. To simplify the presentation, the Analytic Toolkit indices were combined using factor analysis. Two factors were obtained, Factor One called *ATK Knowledge Building Inquiry Index (i.e. note created, scaffold, no. of note read, views worked in, percentage read, word per note)* explained 41% of the variance, and Factor II called *ATK Knowledge Building Visual Organization Index (keyword use, note link)* explained 16.7% of the variance. Correlation shows that quantitative and qualitative measures of knowledge building were related -- ATK Inquiry was related to portfolio (r = .53, p<.001); domain understanding was significantly correlated with ATK Inquiry Index (r = .22, p< .05) and with portfolios (r = .34, p< .01). A multiple regression analysis was conducted to examine the roles of knowledge building measures with prior academic achievement entered first, followed by ATK Inquiry Index, followed by Portfolio scores. Results indicated that academic achievement (Grade 8 scores) contributed significantly to domain understanding. When ATK participation scores were entered, there were small additional variances and the changes were not significant. When portfolio scores were entered, there was an increase in an additional 5% variance and the changes were significant (Table 2). These findings suggest that over and above academic achievement, portfolio scores contributed significantly to domain understanding.

Table 2: Multiple regression of academic achievement, participation, and portfolios on conceptual understanding.

	R	R^2	R^2 Change
Academic Achievement	.35	.12	.12***
Forum Participation	.36	.13	.009
Portfolio Scores	.41	.17	.04*

Characterizing and Tracking Individual and Collective Knowledge Growth

Collective Knowledge Building and Inquiry Thread

Quantitative Analyses. To examine further how students collaborated and how they made knowledge progress, we selected the largest note cluster, consisting of 102 notes of 19 students' responses and questions for assessing knowledge-building discourse. Knowledge building is the creation and improvement of ideas in which ideas are evaluated, revised and tested. Members contribute their problems and different ideas to the database driven by their personal as well as communal interests; they contribute notes and read, build on, rise-above and reference each others' notes. Using the system from Zhang et al (in press), analyses of notes in this large inquiry thread showed there were 79 conceptual comments (7%) in which 32, 24, 8, 16 and 1 notes can be classified into the following categories: (1) deep ideas, (2) stated alternative ideas, (3) questions for peers, (4) providing resource materials for inquiry, and (5) rise-above synthesis note.

We also examined whether the quality of students' responses improved over time. Students' questions were coded on a 4-point scale for depth of inquiry, and their responses were coded on a 7-point scale to distinguish the levels of depth of explanation. Results showed that there were 22 'depth of inquiry' and 94 'depth of explanation' notes. Analyses showed that 68 % of the notes were high-level questions (Level 3 - 4) and 32.6% were high-level explanatory responses (Level 4 - 5). A high level of questions may have the potential to trigger investigation and exploration and knowledge building discourse needs to be sustained by a deeper level of explanation. To examine growth over time, we broke down the notes further into two periods to see the changes in the quality of the notes (Table 3). Analyses revealed that there was a decrease in the number of low-level inquiry and explanation notes but an increase in the posing of high-level inquiry, and explanation notes in period 2. The results indicated that this group of students engaged progressively in a deeper level of knowledge building.

Table 3: Changes in depth of inquiry and depth of explanation over time for an inquiry thread.

	Depth of Inquiry		Depth of Explanation	
	Low-Level	High-Level	Low-Level	High-Level
Period 1	4	5	34	17
Period 2	1	10	15	31

Qualitative Analysis of Discourse. We further analyzed the largest note cluster (102 notes), identified in terms of the knowledge building principle of *Progressive Problem Solving/Ideas Improvement* to see how knowledge building evolved. Students' improvable ideas and growing collective knowledge can be illustrated in a schematic representation showing how new questions and ideas emerged. Figure 1 shows how a simple problem of overfishing evolved and grew with diverse ideas focusing on the controversy about using DNA (Use of DNA Technology as an alternative). The discourse continued to deepen and improve when students discussed DNA in terms of different aspects (ecological, ethical, economic), and led to further problems and solutions (Need to look for alternate effective solutions) and redefinition of the cause of overfishing (Who should be responsible?). Analyses of the discourse showed how a simple problem generated by students (overfishing) became an object of inquiry in this community. Here the schematic representation captures the evolution of ideas and knowledge progression in this community of inquirers as students opened up new issues and concerns. The note cluster illustrated how diverse ideas helped to spark progress and how the discourse evolved and improved with new problems and new ideas emerging with different students contributing to collective knowledge advances.

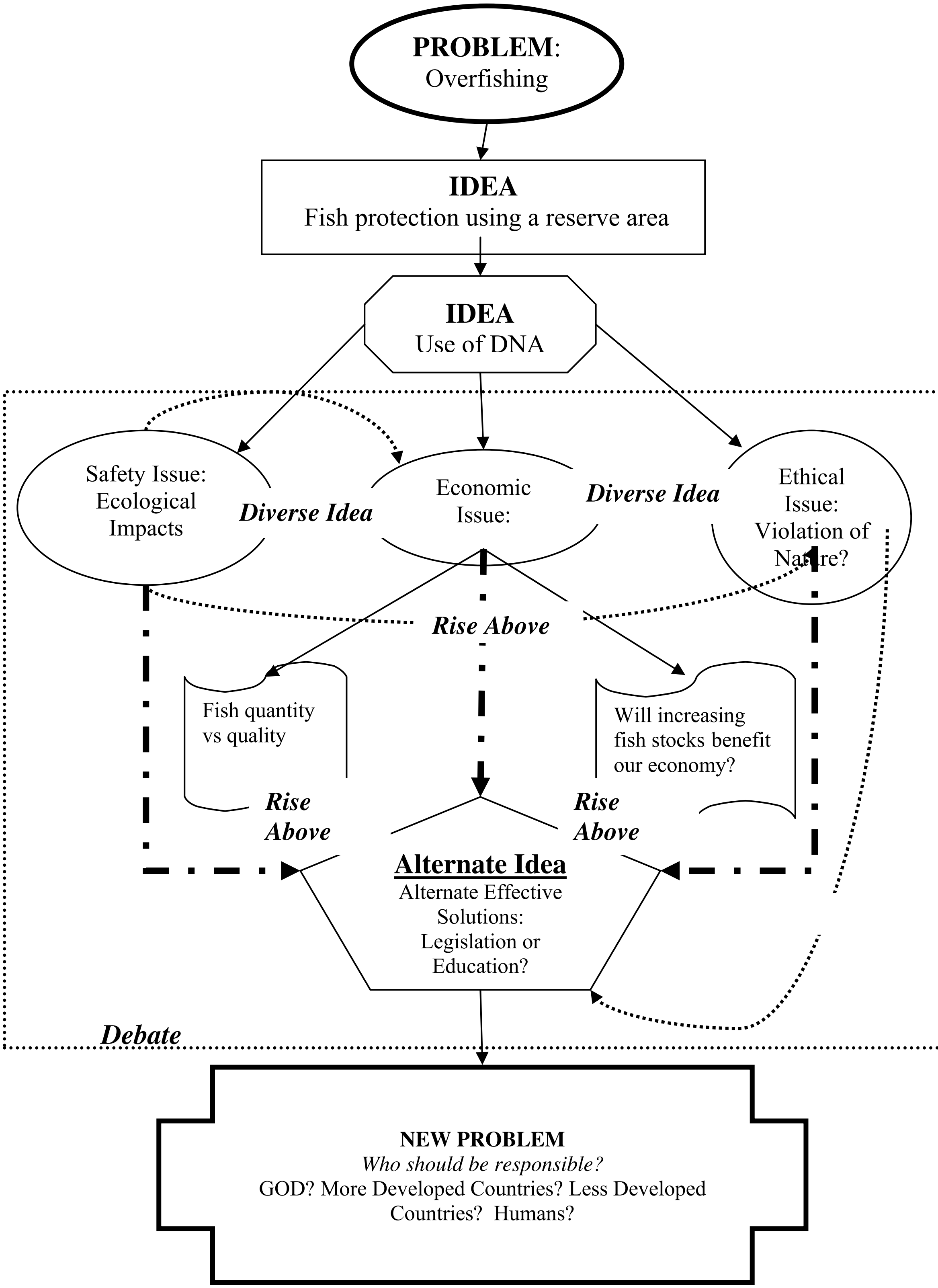

Figure 1. A schematic representation of emergent problems and ideas in an inquiry thread.

Knowledge Building Portfolio and Group Review

We included excerpts from a student's portfolio guided by knowledge-building principles to show how students reflected on collective knowledge building in their own discourse (Figure 2). Not surprisingly, many students chose the cluster on 'overfishing' illustrating knowledge growth. As the portfolio entry shows, the student documented the collective growth of knowledge in the community and explained why he thought it illustrated progressive problem solving; he examined different levels of contribution from his classmates using the rubrics and reflected metacognitively on his own contribution and understanding.

> *Sub-Theme* Because of overfishing, fish stock fluctuates and they affect the fishermen and food supply badly in some developing countries. Our classmates suggest that we can try to apply DNA to the fish so as to change their DNA to let them reproduce faster to solve the problem. This cluster is discussing the advantages and disadvantages of using DNA to fish in order to discuss the [possibility] of using DNA to solve the problem of overfishing. *Progressive Problem Solving* This cluster consists of many notes, they always pose notes providing better [ideas] and further supplementary explanations of the information. They discuss all the advantages and disadvantages of using DNA to [see if they] can solve the problem. They give further room for readers to think about…. For example [1] Changing DNA isn't a solution. This classmate has raise[d] the disadvantages of changing DNA at first, after reading other notes, he even [found] other notes [dealing with] the disadvantages of changing DNA. [2] About the disadvantages of changing DNA of the fish. Classmates make good use of raising questions to improve their theory. Raising questions continually can help to improve ideas and give further supplementary explanations of the idea….Although this is a good cluster, there are still some good and bad questions.….Example of good answer: [3] DNA~Good/Bad This note has 2 features, he [describes] a possible situation of changing fish DNA [and] even shows his personal view of changing DNA. However, he can make a further explanation [and] his prediction would be better….*What I have learned.* From this cluster, I have learned there are many methods to solve the problem of overfishing not just reducing the population….

Figure 2. An example of a portfolio notes showing use of principles and rubrics.

Discussion

We have designed an assessment approach to characterize and to foster collective knowledge advances in Knowledge Forum. Primarily we turned over agency to the students, asking them to assess the community's knowledge advances in the computer discourse, using rubrics, group reviews and portfolios. Our findings indicate that the students provided with knowledge-building principles performed better than those without principles on ATK participation, portfolios and domain understanding; the effects were more pronounced for low achievers than for high achievers on several measures. Portfolio scores predicted domain understanding over and above the effects of academic achievement. Discourse analyses and portfolios helped characterize knowledge building as progressive inquiry and idea improvement. These analyses also provide insights about how such concurrent, embedded and transformative assessment might scaffold both collective and individual advances.

Characterizing and Fostering Knowledge-Building

We have replicated and extended earlier findings on roles of knowledge-building portfolios for characterizing and fostering knowledge building (Lee et al., 2006; van Aalst & Chan, 2007). The present results showed the roles of knowledge-building principles and portfolio assessment on knowledge building and domain-related understanding. Consistent with earlier work, we found that the knowledge-building portfolio is a useful artifact to capture and *characterize* collective knowledge advances. Each portfolio is not an *individual* work – it is based on the *collective* efforts of students tracking their own growth in their understanding of certain ideas. These portfolios have pedagogical benefits and they might also help address theoretical issues of how we can assess collaboration and group cognition (Stahl, 2006). Primarily, knowledge-building portfolios consisting of contributions from various members in the community might help to illuminate the nature and dynamics of knowledge building focusing on idea improvement. More importantly, these e-portfolios that assess and document students' growth over a sustained period of time are somewhat different from the common approach of analyzing collaboration based on minute-to-minute moves. The way these portfolios show a growth trajectory over time may provide another approach for examining how new ideas can be *created, refined and sustained* in collaboration.

Our results indicated that students using knowledge-building principles to assess their own and community work performed better than those without the help of knowledge-building principles. These findings suggested that helping students to recognize knowledge building episodes and to explain them might be important to help them engage in more knowledge building. When they browsed the database they were better able to identify good examples and become more metacognitive. Students engaged in examining their own and community knowledge advances might be more likely to engage in co-construction and thus developed deeper understanding of domain knowledge. This study examined portfolios and we refined their use, helping students to assess both individual and group contributions using rubrics of depth of inquiry/explanation and group reviews. We noted that students made reference to individual notes using rubrics as well as group progress in portfolios. Students discussed, evaluated and rated each of the exemplary notes as well as the cluster as a whole and considered knowledge building in the context of how different notes or ideas improved collectively in sustaining knowledge building discourse. Portfolio assessment extended with rubric evaluation helped the students to identify individual work and community's progress as well as to help them reflect metacognitively on their own understanding

Tracking Knowledge Growth in the Community

As knowledge building focuses on improvable ideas, this study also provides some ways to show how we tracked student growth. ATK indices showed that students made gains and those using the principles made more gains over time. We also examined whether students had made knowledge advances focusing on the analyses of a large inquiry thread. We rated each note in the cluster using rubics of inquiry and explanation so as to explore the relationship between individual understanding and collective knowledge building. Rating of the notes suggested that students wrote deeper questions and explanations in later parts of the discourse compared to earlier phases.

We also attempted to employ a schematic representation to trace idea improvement episodes in online discourse. Findings show that the inquiry thread that we have examined consists of a large proportion of high-level inquiry and explanatory responses. Conceptual comments could generate more ideas, sustaining the inquiry for alternative and diverse ideas for reaching a deeper level of understanding for the community (Zhang et al., in press). Analysis indicates that students scaffolded by knowledge-building principles could generate more high-level inquiry and explanatory questions and responses. The schematic representation we have produced illustrates aspects of how new ideas and new problems emerge in the knowledge building community. One simple problem of overfishing aroused immense interest in students who worked on the idea of using advanced technology as a solution. In the event of debating over the feasibility of changing DNA of fish, new ideas emerged and new problems came into existence as "Who should be responsible? God? More developed countries (MDCs) or Less developed countries (LDCs)? Or Humans?" Questions centred on problem-based inquiry would engage students in knowledge-seeking inquiry. They formulated questions around problems; they began to identify difficulties with their understanding, and constructed explanations to guide their inquiry.

Knowledge Building and Student Diversity

This study also showed that, guided by knowledge building principles, students, both high- and low-achievers, engaged in productive knowledge practices. Most interestingly, there were some interaction effects indicating that knowledge building principles had more effects for students in Low-Achieving classes on gains in participation and domain understanding. This extends our earlier work, suggesting that knowledge building principles and portfolios can benefit both students of high- and low achievement levels. These findings are consistent with research on higher-order thinking for low-ability students (Zohar & Dori, 2003) and recent work on knowledge building for high and low achievers (Niu & Van Aalst, accepted).

Many teachers believe knowledge building and other forms of high-level instruction would be difficult for low-achievers. The contextual background in Hong Kong, with streaming of students into high- and low-ability groupings, provided us an opportunity to examine whether knowledge building principles could be applicable for low achievers. We did find that high-achievers outperformed low-achievers on portfolios, possibly due to the more complex nature of the task. Nevertheless, for Forum participation, we found low-achievers gained more than high-achievers when they were scaffolded by knowledge-building principles. We even found that low-achievers benefited more than high-achievers on domain understanding when provided with principles. Such findings are interesting because often teachers will see student ability as barriers. Knowledge building focuses on collective work rather than individual competence. Similar to other cognitive models, such as fostering a community of learners focusing on students as teachers (Brown & Campione, 1994), the emphasis on collective progress in knowledge building might provide another pedagogical model to help work with students of diverse abilities.

In sum, we extended our earlier work examining portfolio assessments and demonstrated more clearly the roles of knowledge-building principles using group review journals, portfolio and rubrics. Students constructed their collective understanding through analysing the online discourse, and group review journals and portfolios were used to mediate the interaction between individual and collective knowledge advances. Our study has shown that concurrent and embedded assessments are useful for both high- and low-achieving students when given appropriate scaffolds. When students are provided with the principles, they became more aware of what productive discourse entails; the principles are scaffolds for their knowledge-building progressive inquiry. How individual and collective agency can be supported by assessment in the knowledge-building community are important research issues that need to be investigated further.

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