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Knowledge Building with Senior Secondary Students: a New Zealand Study

Kwok-Wing Lai, *wing.lai@otago.ac.nz*
University of Otago, Dunedin, New Zealand

Abstract
This paper reports a study using the knowledge building community approach developed by Scardamalia and Bereiter (2010) to advance senior secondary students' interest and understanding in science**.** Fifty-six Year 13 students from rural and low decile (in terms of social economic status) participated in this one-year study. These students attended two five-day residential schools (in January and July) at a New Zealand research-intensive university. Throughout the year a virtual school was set up, using the knowledge building approach and the networking software *Knowledge Forum*, to support the participants to develop their capability in creating and building knowledge in science by developing, building-on, and critiquing ideas in an online community of inquiry. Data collected from the questionnaire surveys, interviews, and content analyses clearly showed that the knowledge building process was effective in enhancing the participants' understanding and knowledge of science, and had a positive impact on their schoolwork. What the participants valued most was the opportunity to engage with like-minded people and the opportunity to discuss academic matters and challenge each other's viewpoints, both face-to-face and online.

Keywords
Knowledge Building, computer-supported collaborative learning, science education, inquiry-based learning

INTRODUCTION
This paper documents a study using the knowledge building community approach developed by Scardamalia and Bereiter (2010) to advance senior secondary students' interest and understanding in science. This study, titled the Otago University Advanced School Sciences Academy (OUASSA) project, was a two-year (2011-2012) project funded by the New Zealand Ministry of Education and the University of Otago to support potentially high achieving Year 13 students from rural/provincial or low decile (low SES) schools to cultivate their interest in science and enhance their ability to excel in the NCEA (National Certificate of Education Achievement) public examinations. In each year of this project, a cohort of more than 50 students from across New Zealand were selected to participate in two five-day residential schools (in January and July) at the University of Otago. Throughout each year a virtual school was set up using the knowledge building approach and the networking software Knowledge Forum to support the participants to develop their capability in creating and building knowledge in science by developing, building-on, and critiquing ideas in an online community of inquiry. This paper will report findings of the virtual school gathered from the second cohort (students admitted in 2012). Findings from the first cohort (students admitted in 2011) were reported in Lai (2012).

THE KNOWLEDGE BUILDING COMMUNITY APPROACH

Information and communication technology (ICT) has been considered a change agent, having the potential to facilitate students to acquire the metacognitive, problem solving, collaborative, and learning how to learn skills that are required to work with and create knowledge in the knowledge society (Lin & Sullivan, 2008). To this end, a myriad of technology-enhanced learning environments have been designed and researched internationally in the last two decades. These include projects such as problem and project-based learning (Krajcik & Blumenfeld, 2006), discovery learning (de Jong, 2006), anchored instruction (CTGV, 1994), cognitive apprenticeships (Collins, 2006), and knowledge building communities (Scardamalia & Bereiter, 2006). We now understand that to have a sustained impact on teaching and learning, technology-supported learning environments need to be well designed, based on learning and pedagogical principles, and integrated into the school curriculum (Lai, 2008). One of the very few of these technology-supported learning environments that is based on a well-designed pedagogical model is knowledge building communities, developed by Scardamalia and Bereiter (2006). This model has been developed from over two decades of cognitive research on intentional learning, and it views learning as a constructive process of knowledge building (Scardamalia & Bereiter, 2010). The goal of knowledge building is "the production and continual improvement of ideas of value to a community" (Scardamalia & Bereiter, 2003, p.1370), and the role of the teacher is to guide learners to "engage in extended questioning and explanation-driven inquiry" (So, Seah, & Toh-Heng, 2010, p. 480). The knowledge building pedagogical model developed by Scardamalia & Bereiter (2006) has 12 principles (refer Table 1). Knowledge building research has shown that by immersing in knowledge building communities, students can develop the competencies and cultural practices which are needed in the knowledge society (e.g. Bielaczyc & Ow, 2010; Fong, 2010; Lee, Chan, & van Aalst, 2006; Oshima, et al., 2006; Zhang, Scardamalia, Lamo, Messina, & Reeve, 2007).

Table1: Twelve pedagogical principles of knowledge building

Real ideas, authentic problems	Democratising knowledge
Improvable ideas advancement	Symmetric knowledge
Idea diversity	Pervasive knowledge building
Rise above	Constructive uses of authoritative sources
Epistemic agency	Knowledge building discourse
Community knowledge, collective responsibility	Concurrent, embedded, and transformative assessment

In knowledge building research, Knowledge Forum is used to support online knowledge building discourses. Knowledge Forum has a set of scaffolding tools to engage in online discourse to develop, reformulate, critique, and build on ideas on authentic questions to advance personal understanding and communal knowledge. In Knowledge Forum, views (similar to discussion forums) are set up for participants to contribute and develop ideas. Figure 1 is a screenshot of a view (a discussion forum) set up in the OUASSA project. Participants contributed ideas by posting "notes" or "annotation notes" to these views. Notes can be built onto each other and links between notes are displayed on the view. Figure 2 is an example of a note. The yellow notes at the bottom of this note are annotation notes. A set of scaffolding tools is available on the left-hand side bar. To kick-off a knowledge building discussion, the teacher typically would post an opening note to ask a broad question or post a problem. The starter questions may also be posted by the students. Students then contribute ideas and build-on each other's ideas to develop theories and solutions. To provide evidence to support their theories, they would read articles, search the Internet for information, or conduct experiments. The scaffolding tools embedded in Knowledge Forum are used to support students to build theory (My theory, A better theory, etc.) and ask questions (I need to understand).

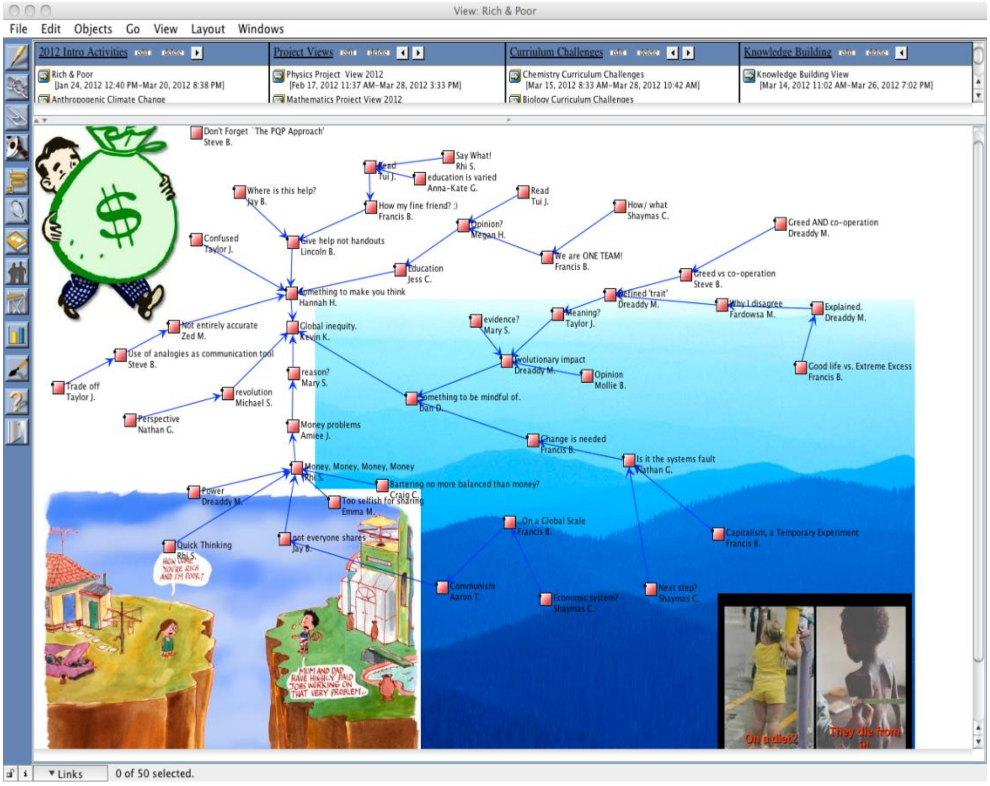

Figure 1: Example of a view

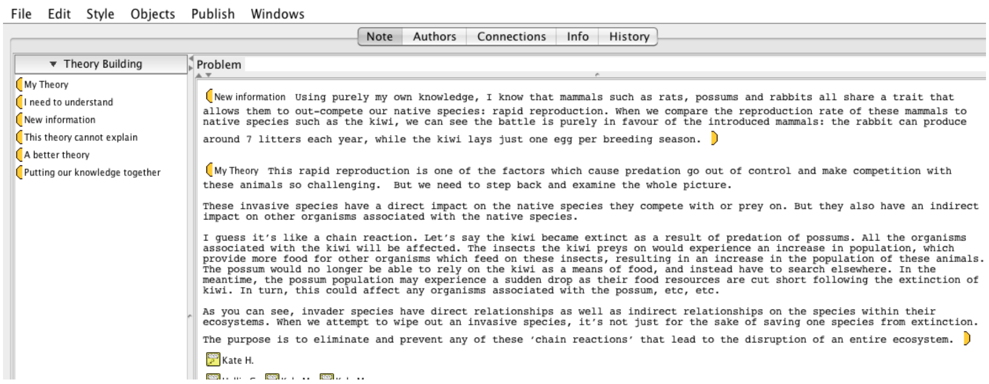

Figure 2: Example of a note

THE STUDY

Research questions

While knowledge building research has been undertaken in a number of countries in the last two decades, the majority of them were conducted at the primary level, and it is not clear how the knowledge building approach and Knowledge Forum can be effectively integrated into the senior secondary school curriculum where there is far less flexibility in its implementation. Also, no research has been conducted to investigate how the knowledge building pedagogy can be used to support distance learning. This study was conducted to address several questions. For the purpose of this paper, we will focus on one question: How effective was the knowledge building community in supporting senior science students to build knowledge in science as a community of learners?

Procedures

During the January residential school, the knowledge building approach was introduced to the students, and a workshop was run to provide students with a hands-on experience in using Knowledge Forum. In the July residential school, the knowledge-building model was again discussed. In the 2012 cohort, the topics of discussion were related to the science projects that students undertook during the January residential school. Students were asked to participate in one of the four main discussion forums (math, marine science, zoology, and physics) during the first and second school terms (February to July). During the third term (July to September), four additional forums were set up (computer science, chemistry, biochemistry/genetics, and geography). While students were asked to participate in one of the forums during each period, many of them read and contributed ideas in other discussion forums as well.

Data sources

Both quantitative and qualitative data collection methods were employed in this evaluation. These methods included:

- Questionnaire survey – A questionnaire was administered to the students during the January residential school. A second questionnaire was administered during the July residential school. Some items of the questionnaires were adapted from the literature (New Zealand Council for Educational Research (2006); Menis (1989); Shell et al. (2005)) and others were constructed by the research team.
- Interview – A sample of students was interviewed in July during the residential school.
- Content analysis – Four discussion forums in Terms 1 and 2 were selected for analysis.

Participants

Fifty-six students participated in this study, with the majority of them (79%) being New Zealand Europeans, and only 9% of its participants were either Māori or Pacific Islanders. Over three-quarters (78%) of the students came from lower decile schools. Thirty-three and 45 students responded to the pre- and post- questionnaires, respectively. Eleven students (three male and eight female) were interviewed.

RESULTS

Attitudes and learning preferences

The questionnaire developed by Menis (1989) was used to see whether there were any changes in students' attitudes towards science. While the composite scores of all the items for the science attitudes scales showed that the participants had positive attitudes toward science for both surveys (mean Survey 1 = 2.28; mean Survey 2 = 2.57), there were no significant differences in the scores between the two surveys ($t(21) = -1.652$, $p = 0.113$). This is perhaps not unexpected as students participating in this project were all high achieving science students who already had a very positive attitude towards science.

One of the key pedagogical principles in knowledge building is that students are empowered as epistemic agents to take initiative in their own learning, and to self-regulate their learning process. The SPOCK instrument developed by Shell and his colleagues (2005) was adapted to measure the changes of students' learning preferences and styles. Thirty-eight items were included in the questionnaires to measure six factors: (a) collaborative learning (5 items); (b) knowledge building (9 items);

(c) teacher directed classroom (5 items); (d) lack of initiative (7 items); (e) self-regulation (6 items); and (f) question asking (6 items). These items were measured on a Likert-type scale, with 1 = almost never, and 5 = almost always.

The results of the paired samples t-tests of the 24 students who completed both Surveys 1 and 2 showed that in general, students reported moderate levels of collaborative learning, knowledge building, initiative, teacher directed classroom instruction, self-regulation, and question asking during the survey period. Differences in learning styles and preferences between Surveys 1 and 2 were found for the factors of lack of initiative, self-regulation, and question asking. For the lack of initiative factor, there was an improvement in the participants' initiative in learning between Survey 1 (Mean = 2.57) and Survey 2 (mean = 2.17) with t(18) = 3.003, p = 0.008) and the effect size was considered large at 0.58. For the self regulation factor, there was an improvement in the participants' self-regulation in learning between Survey 1 (Mean = 3.02) and Survey 2 (mean = 3.42) with t(20) = – 2.523, p = 0.020) and the effect size was considered large at 0.49. For the question asking factor, there was an improvement in the participants' ability to ask questions to enhance learning between Survey 1 (Mean = 3.74) and Survey 2 (mean = 4.13) with t(17) = – 2.261, p = 0.037) and the effect size was considered large at 0.48 (refer Table 2). The findings from the questionnaire surveys indicate some positive effects on student's epistemic agency.

Table 2: Paired samples *t*-tests results for differences in learning preferences between pre- and post-survey

				Paired differences					
				Mean	Std dev	*t*	*df*	*p*-value	Effect Size
Overall Learning Preference	S1	3.40	0.312	0.04	0.344	0.380	12	0.711	–
	S2	3.36	0.251						
Collaborative Learning Factor (CL)	S1	3.78	0.727	0.36	0.967	1.763	21	0.092	–
	S2	3.42	0.964						
Knowledge Building Factor (KB)	S1	3.53	0.371	0.02	0.704	0.108	18	0.915	–
	S2	3.51	0.644						
Teacher Directed Classroom Factor (TDC)	S1	3.28	0.451	– 0.30	0.814	– 1.65	19	0.116	–
	S2	3.58	0.597						
Lack of Initiative Factor (LI)	S1	2.57	0.431	0.40	0.578	3.003	18	0.008	0.58
	S2	2.17	0.537						
Self-Regulation Factor (SR)	S1	3.02	0.518	– 0.40	0.735	– 2.52	20	0.020	0.49
	S2	3.42	0.903						
Question Asking Factor (QA)	S1	3.74	0.454	0.39	0.729	– 2.26	17	0.037	0.48
	S2	4.13	0.848						

Note: 1 = almost never; 5 = almost always

Creating knowledge

All the online discussion notes were archived and all four project forums conducted in the first two school terms were analysed. Table 3 summarises the participation rates of the students in the Knowledge Forum discussions.

Table 3: Participation rates of Knowledge Forum

Forum	No. of partici-pants	No. of notes and annota-tions	No. of par-ticipants contributing notes	No. of partic-ipants read-ing notes
Maths Project Group	11	50	9	10
Physics Project Group	19	76	18	18
Zoology Project Group	19	103	16	19
Marine science Project Group	19	103	16	17

We were able to identify development of ideas in the knowledge building process in each view, although the extent of development of ideas varied from forum to forum. We can see that many students have contributed ideas and theories during the discussion, and some have also provided resources to facilitate discussion. In assessing idea development, the first step was to identify whether there were clusters of discussion in each discussion forum, and how active these clusters were in terms of both the number of active participants and the frequency of participation. It is particularly significant to look at the number of contributors who have contributed more than one note in a forum. If the number is low, it shows that ideas have not been followed up and further developed by the original contributors of ideas.

Table 4: Contributions to the discussion forums

Forum	Cluster	Notes and annotations	Contributors	Contributors contributed more than one note/annotation
Math	M1	16	7	3
	M2	8	5	2
	M3	2	2	0
	M4	6	2	1
Marine science	S1	15	9	5
	S2	17	9	5
	S3	35	14	5
Zoology	Z1	27	11	7
	Z2	18	7	4
	Z3	8	6	2
	Z4	4	4	0
	Z5	5	4	1
	Z6	5	3	2
	Z7	7	6	1
Physics	Y1	6	5	1
	Y2	6	5	1
	Y3	19	16	2
	Y4	24	12	9

As can be seen from Table 4, in each of the forums there were large clusters of discussions, and participation was very active. Also, in several clusters (e.g., Z1, Y4), we can see that several participants have contributed more than one note, showing that the group may be in the process of developing communal ideas. The following examples illustrate the development of ideas in these clusters.

Example 1

The first example was an excerpt from a group of students working on the Zoology project.

Student H: Are there any New Zealand examples of species that are non-native or alien not becoming an invasive species?

Student A: Building on this theory…. Maybe we need to investigate into

	which non-natives that have been classified as "invasive" can be actually used for good.
Student H:	These invasive species have a direct impact on the native species they compete with or prey on. But they also have an indirect impact on other organisms associated with the native species. I guess it's like a chain reaction.
Student A then built-on:	If we do, as the previous note said, take up the theory that one of the reasons possums are so successful in New Zealand is due to their high birth rate. We can certainly then say that this creates a chain reaction.

This discussion had a huge impact on the group, as can be seen from the synthesis notes that students were asked to contribute at the conclusion of the discussion to reflect on the ideas that have been developed by the community:

> Student A proposed an intriguing theory…. Student A raised what I believe to be the most important idea…. Student A's theory is realistic and (in my opinion) holds great potential. (Student H's synthesis note)
>
> Student H's post 'Chain reactions' which helped me understand that invasive species have direct relationships as well as indirect relationships on the species within their ecosystems. (Student O's synthesis note)
>
> A very informative discussion for someone who doesn't do biology, yet still wants to help out in our environment. (Student B's synthesis note)
>
> The post by Student H titled 'Chain Reaction' really made me think about my 1080 [an assessment standard] essay from school and the reasons for keeping possums around (Student A's synthesis note).

Example 2

Student A:	(Proposing a theory) I think that the engineer counts 9 as a prime number because in his field, he approximates numbers rather than using exact measurements.
Student F:	(Critiquing Student A's theory) If he approximates his numbers, how does he ensure that his buildings doesn't [sic] fall to pieces?
Student F:	(Proposing his own theory) Engineers take on the views of the mathematician and the physicist and chooses what he wants to believe…he applies the reasoning of maths and physics to real life situations, he does not actually make theories of his own.
Student T:	(Critiquing Student F's theory) When a person presents a new theory they should state the assumptions they've made and the reason for making the assumption.
Student Z:	(Building-on to Student T's theory) Even making an incorrect assumption can sometimes be beneficial, as it can encourage you to think in ways you otherwise wouldn't.

This excerpt showed the exchange of different perspectives from the participants and the gradual development of a solution by the group. With the diversity of ideas provided in this view, students could consider the problem from different angles. A student has provided an interesting metaphor for the Knowledge Forum discussion:

> The butterfly effect ... you could use that as a metaphor for *Knowledge Forum*, where you've got all the quarks and bions and misons which are all the individual people and then you've got the galaxies and universes which are the big, overall whiteboards that everyone writes on … screen full of ideas, just new ideas and different ideas … you've got ideas at the start and ideas at the end … middle links. (S03)

Effects on schoolwork

Students in this study were very positive about knowledge building, with 75% of the interviewees stating that they had gained knowledge and to a lesser extent confidence from the knowledge building forums. When asked whether the Knowledge Forum discussions were helpful to their schoolwork, nine out of the 11 interviewees considered it helpful. They also considered that there was a link between the discussions in the Knowledge Forum and their schoolwork. As commented by the following students:

> The discussion on *Knowledge Forum* was quite helpful in sort of broadening your view on topics… *Knowledge Forum* was quite helpful with school work as well. (S39)

> It's helped a lot…in Biology…what we went through was just building on what we've done…and building on each other…I can more confidently write an essay about it now and more confidently speak about 1080. (S04)

For one student (S27), who was the only Physics student in her school, she didn't ask the teacher to teach the topic resonance as she has already learned it in the Knowledge Forum discussion:

> Yes, because I go on there…there was [sic] so many posts on resonance…you'd go on there and read everyone's and by the time you've finished that, you're an expert on resonance. (S27)

The knowledge building process

In this study students were asked to write a synthesis note summarising what they have learned from the knowledge building process. The following was an excerpt from one student, showing how he understood the process of knowledge building:

> For me, the most important thing I got from this exercise was seeing how a group could reach conclusions and come to a consensus even though the individuals in the group have different methods of approaching a problem. I found this valuable because in the past group discussions (not at OUASSA) have seemed to me to be more focused on people trying to prove that their views were 'right', rather than incorporating others ideas. (Student Z)

Students viewed knowledge building as a collaborative effort. As commented by one of the students in his synthesis note, "My theory, which builds somewhat on what other folks have said, and what I have learnt in class and from the Internet [that is his own research]". For another student:

> I love the whole, like the research around knowledge building and…like creating your own knowledge…it's not like you come up with entirely new, brilliant ideas but you build it as a group and I think we definitely have done it. (S39) For some students there has been a lot of excitement in participating in the knowledge building process. For example, according to one student:

> I think for the people that put in the effort to do it, you gain a lot…they kind of took the curriculum and then just extended it a bit further and challenged you to think about like how it applies to the real world…. I checked it at least once a week …between like 10 minutes and half an hour…if you just put in a little bit of knowledge, that can inspire someone else to go off on some other tangent or help clarify something for someone else and I think that's quite powerful…if you've got a group of really…motivated students…it's quite powerful [of] what you can actually come up with…I think that excitement was definitely there…like what are we going to end up creating? What knowledge are we going to end up finding out? (S39)

Another student has summed up his experience well:

> In the actual project, there's knowledge building happening…it might be hard to emulate in a virtual environment, but it is actually happening here and I always feel like that environment is a really good environment to be in. (S16)

DISCUSSION AND CONCLUSION

Findings from the questionnaire surveys, interviews, and content analyses clearly showed that the knowledge building process was effective in enhancing the participants' understanding and knowledge of science, and had a positive impact on their schoolwork. As most of the participants came from low decile and small rural schools, the project provided them an opportunity to meet with real scientists and work with them in advanced science labs, which has greatly increased their understanding and widened their perspectives of the nature of doing science. What the participants valued most was the opportunity to engage with like-minded people and the opportunity to discuss academic matters and challenge each other's viewpoints, both face-to-face and online, which they seldom had the chance to discuss in their small rural schools. There were some technical issues with using the Knowledge Forum software (not discussed in this paper due to space constraints) that needed to be addressed in the future. We understand the international knowledge building research community is currently redeveloping Knowledge Forum as open-sourced, Web-based networking software. The technical issues found in this project should be resolved once this new version of the software is available.

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Biography

Kwok-Wing Lai is Director of the Centre for Distance Education and Learning Technologies at the University of Otago College of Education in Dunedin, New Zealand.