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DEVELOPMENT ARTICLE

Inquiry-based learning and e-mentoring via videoconference: a study of mathematics and science learning of Canadian rural students

Qing Li · Lynn Moorman · Patti Dyjur

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Abstract This research seeks to (1) establish a feasible development and implementation model for an inquiry-based learning environment with e-mentoring using videoconference, and (2) apply the model to examine its impact on rural students' learning. To achieve these goals, we developed a model of inquiry-based learning with e-mentoring (IBLE) based on CII's inquiry model (Community Informatics Initiative 2009; http://inquiry.uiuc.edu/). We then tested the effectiveness of the IBLE model and reported our work in a rural context. Results showed that IBLE had enhanced students' learning, most significantly on their affective development, including increased motivation, broadened understanding, and augmented career awareness. Implications for design and limitations of the study are also discussed.

Keywords Rural education · e-Mentoring · Inquiry · Videoconferencing · Math/science learning · Instructional technology

Excellent science and math education is necessary, not only for college-capable students but also for the workforce, in order to have a strong economy and national defense (Resnick 2006). However, math and science teaching in secondary classes tends to follow a prescribed routine. A traditional teaching approach often means either a heavy emphasis on memorization in math and science classes, or requiring students to solve problems according to a standardized method (National Research Council 2001). Rural students face even more challenges: schools tend to offer a smaller range of courses and they receive less guidance and support regarding career awareness as compared to urban schools (Barbour 2007), partly due to the fact that fewer teachers specialize in particular subfields in the sciences (Crawford 2006). Previous research (Lord and Orkwiszewski 2006; Lapan et al. 2007) shows that inquiry-based learning can mitigate these problems because it holds

Q. Li (✉)
EDT, University of Calgary, 2500 University Dr. NW, Calgary, AB, Canada
e-mail: qinli@ucalgary.ca

L. Moorman · P. Dyjur
University of Calgary, Calgary, AB, Canada

much promise in making math and science learning more relevant and interesting to students. Different from the didactic, prescribed approach, inquiry focuses on higher-order thinking skills and real-world problems that may have many possible solutions, leading to higher motivation, increased retention of factual knowledge (Lord and Orkwiszewski 2006), and more creative approaches to problem solving (Wilhelm and Walters 2006). By emphasizing the learning process through an inquiry approach, as opposed to memorizing factual content, rural students may be better equipped to apply what they have learned to different subject areas. Further, consistent quality career development services can fundamentally improve rural students' career aspirations and development (Lapan et al. 2007).

Mentoring is one way to make an impact on students' career awareness and aspirations. Communicating regularly with a mentor in fields such as math and science can dispel stereotypes while broadening student perceptions about how different professionals apply these subject areas in practice (Bennett et al. 1998). It may not be feasible for rural students to have ongoing meetings with mentors face-to-face due to geographical distance; technological advances however, provide a useful tool to facilitate mentoring and can offer rural students with different opportunities (Single and Single 2005). Using technology to facilitate mentoring can be an eye-opening experience for students who live in rural areas with a limited local economy, if it prompts them to consider possibilities that are outside of their personal experience (Bennett et al. 1998). Further, the promise of broadband interactive technology, such as videoconferencing (VC), to radically change education has been proselytized (Anderson 2008). VC is a real-time method of communicating in different locations through video (Cavanaugh 1999; Anderson 2008). Various levels of government (e.g. Alberta SuperNet) have invested greatly on bringing 'urban priced' high-speed network to rural and other marginalized areas. This has brought significant opportunities and ideal tools for the improvement of educational practice, particularly in rural regions.

Although inquiry-based learning with the support of e-mentoring via VC holds promise, there is a lack of practical and field-proven models adapting such an approach (Li 2007). In this study, therefore, we aim to (1) establish a feasible development and implementation model for an inquiry-based learning environment with e-mentoring, and (2) apply the model to improve rural students' learning of math and science in secondary classrooms.

First, we discuss inquiry-based learning and e-mentoring within rural contexts. Second, we describe the instructional design framework that has guided us in developing an inquiry-based learning environment with e-mentoring. Next, we report on a study implemented in a rural school. Finally, we conclude with a discussion and implications of the project.

Design framework

Inquiry-based learning

Rooted in John Dewey's work, and more recently aligned with constructivist epistemology, inquiry-based learning is "an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding" (National Science Foundation 2005, p. 2). Inquiry, according to Dewey, "is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live" (1938, p. 111). Promoting learning from guided exploration of complex problems and issues via direct experience and inspire their natural curiosity (Lee 2004), inquiry is also an essential skill for coping with the complexity of this information age with many challenges such as information overload (National Science Foundation 2005).

Galileo Educational Network (2008) describes general characteristics of inquiry-based learning: projects focus on authentic problems and issues that are relevant to students and to the real world. Students play a key role in defining the questions to be studied as well as the direction that learning takes. Learning is done through field work, design, construction, interviews, research, and other types of active exploration that lead students to new insight; deep understanding is the goal, not regurgitation of facts. Teachers facilitate the learning process by guiding students and structuring the learning environment.

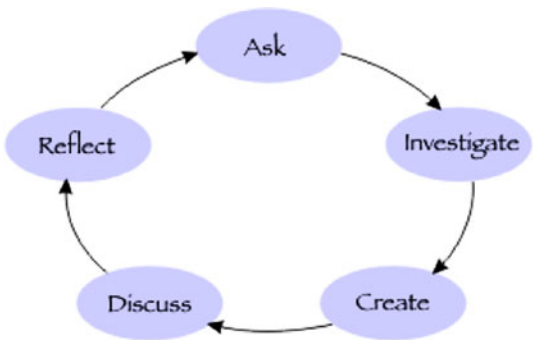
Inquiry in math/science classrooms is characterized by hands-on activity and critical thinking (Gerber et al. 2003). Students are encouraged to explore, do research, reflect on what they have learned, communicate their findings, and evaluate their knowledge (van Zee and Roberts 2006). Rather than forcing students to follow a prescribed routine, scientific inquiry prompts students to ask interesting questions, plan and conduct investigations, use appropriate techniques to gather data, think critically about evidence and possible explanations, analyze alternative explanations, and communicate their arguments (Wilhelm and Walters 2006). Benefits of using an inquiry approach include increased retention of factual knowledge, more flexibility/creativity in problem solving, and an increase in student motivation (Lord and Orkwiszewski 2006).

The CII inquiry model (Fig. 1) developed by researchers at the University of Illinois-UC describes a spiral path of an inquiry process. In this model, inquiry starts with meaningful questions inspired by students' natural curiosity about real world experience (i.e. Ask). This logically leads to investigation where students are gathering information, studying phenomenon, conducting experiments, interviewing in an attempt to answer the questions or solve the problems (Investigate). When the information begins to connect, learners perform the creative task of shaping ideas and significant thoughts that form new knowledge (Create). Next, learners discuss their ideas with others and build communities through shared knowledge (Discuss). Then the learners step back, reflecting on the questions and the research path, and possibly make new decisions (Reflect), which leads to the new round of inquiry (Community Informatics Initiative 2009).

e-Mentoring

Mentoring can be an important aspect of inquiry as it allows students to ask questions that matter to them and get answers from an expert who can give complex, authentic answers. Mentors are able to use real life examples, stimulating interest and further student inquiry

Fig. 1 Inquiry model (Community Informatics Initiative 2009)



(Galileo Educational Network 2008). They can also be instrumental in dispelling stereotypes, providing real-life examples of well-rounded people with balanced lives and showing students how technical fields can involve working with people, contributing to a better future, and advancing society (Bennett et al. 1998). Communicating regularly with a mentor can raise student interest and awareness in a career direction that a student has not considered previously (Packard and Nguyen 2003).

When students are given career development skills in secondary school, there is a significant difference in career aspiration after graduation, and these students often realize advantages (e.g. more satisfied about their career) in young adulthood (Lapan et al. 2007). Like in high school, career awareness is important in the middle grades because students must decide which courses to take in high school, and these decisions can affect eligibility for university programs (Osborne and Reardon 2006). Guidance and counseling in the areas of academic achievement, expectations, goal formation, and exploratory actions will help students to make more informed decisions about their schooling and career aspirations (Lapan et al. 2003).

Mentoring can be particularly crucial for students in rural areas because they face various challenges including limited access to higher education, less variety of courses offered, narrowed school curricula, and a lack of work-related experts as role models (Barbour 2007; Crawford 2006). In addition, they often have lower career aspirations and higher expectations of entering the workforce immediately after graduation than their urban counterparts (Lapan et al. 2003).

Technology provides useful tools to implement inquiry strategies and mentoring that are otherwise difficult to accomplish, particularly in rural regions (Kubicek 2005). Using computer mediated communication (CMC), a convenient and relatively inexpensive way to communicate (Mizell 1999), students can connect with mentors and interactions can occur over weeks or months, allowing students time to reflect and grow. Students can learn about their mentor's chosen profession, and build self-esteem and confidence in a supportive environment (Single and Single 2005). e-Mentoring can be an eye-opening experience for rural students and prompts them to consider possibilities that have been outside of their personal experience (Lapan et al. 2007). It also is more permanent than a conversation, whether face-to-face or over the telephone, so that students can refer to conversations at a later time (Bennett et al. 1998). Benefits of e-mentoring are categorized as informational, psychosocial, and instrumental (Single and Single 2005). For example, inquiry projects that allow students to interact with e-mentors, using curriculum contents for authentic purpose, illustrating how these subjects apply to different careers, has the potential to broaden students' perceptions about the types of careers that are related to these subject areas (van Zee and Roberts 2006).

Videoconferencing (VC) holds particular potential for educational applications (Cavanaugh 1999; Anderson 2008). Although more expensive than mentoring through e-mail, the benefits of VC might make the extra expense worthwhile. Some of the benefits of VC include having the feeling of meeting the other person, gathering differing viewpoints, and sharing ideas (Mizell 1999). It can help participants to experience a personal connection over distance as they can make eye contact and see other people's expressions. One potential downside of VC—a design tradeoff—is that it does not provide "permanent" conversation unless the sessions are recorded.

The model of inquiry-based learning with e-mentoring (IBLE)

Establishing an inquiry-based learning environment should be a carefully choreographed process that involves a high level of organization, planning and structure (Rankin 2000).

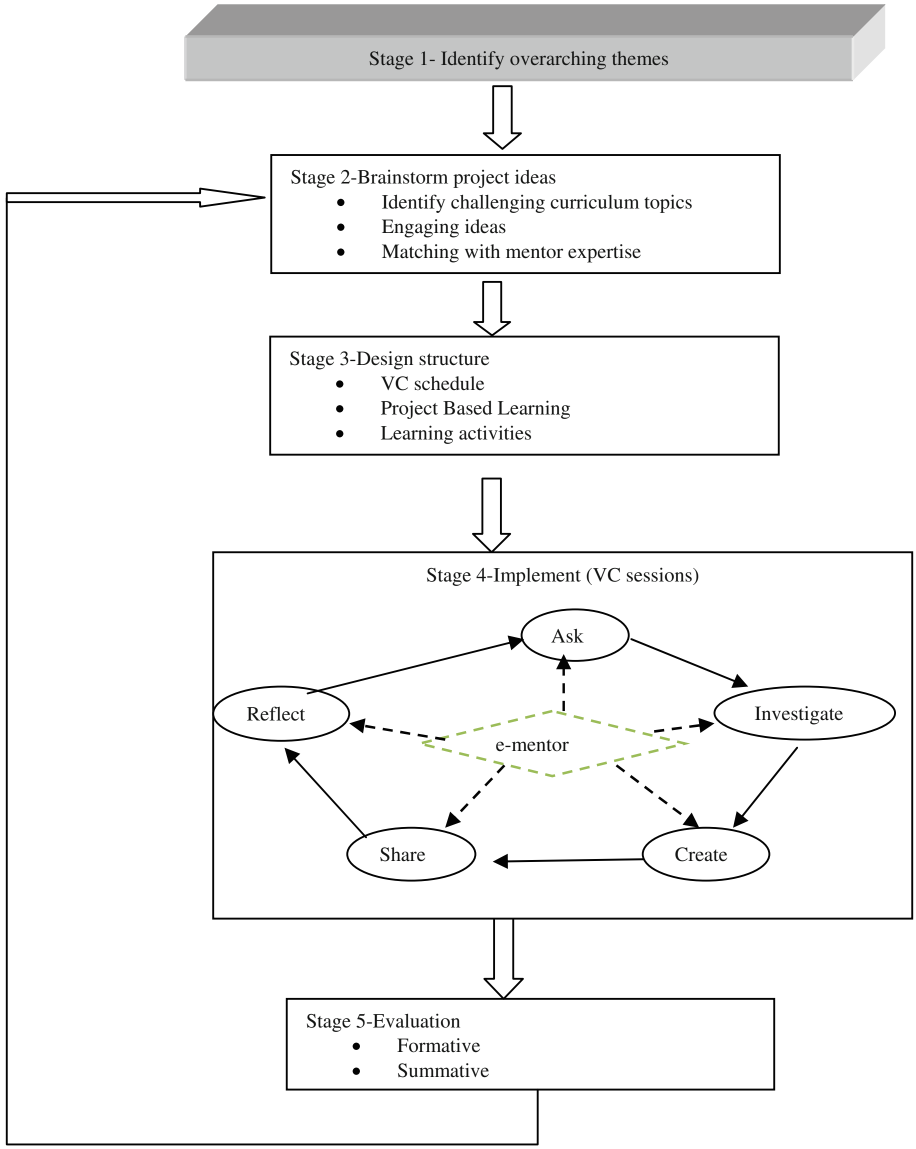


Fig. 2 Inquiry-based learning with e-mentoring (IBLE) model

We have developed a model of inquiry-based learning with e-mentoring (IBLE), as shown in Fig. 2, adapting the CII's inquiry model (2009) discussed above. In the following we describe the IBLE model, substantiated by our "Bear Project"—one of the student inquiry projects.

The IBLE model starts (Stage 1) with the identification of an overarching theme which should reflect students' content learning and connect to real life. All the learning activities are anchored to this theme which covers an extended learning period (e.g. a term). Next, in Stage 2, researchers, e-mentors, and teachers/educators work collaboratively to brainstorm ideas for possible inquiry projects. In this stage, a thoughtful consideration of the answers to the following three questions provides foundations for the design of students' inquiry projects: (1) what are the curriculum topics that need most attention? (2) What topics will engage students? (3) How can we match e-mentors expertise with curriculum so that students can benefit the most from their interactions with the e-mentors?

Stage 3 involves designing the structures of student inquiry projects and associated learning activities. This includes the determination of the frequency, schedule, and topics of VC sessions, as well as the development of other learning activities that naturally integrate VC sessions, e-mentors' interaction with learners, and curriculum contents. When designing curriculum activities, inquiry-based learning principles call for the consideration of (1) hands-on experience, (2) collaborative learning; (3) simulations (including demonstrations and role-playing); and (4) multidisciplinary approaches (Schwartz et al. 1999; Quintana and Fishman 2006; Hmelo-Silver et al. 2007) that support teacher guided learner-focused exploration of authentic questions for deep learning.

In Stage 4, the inquiry projects are implemented, during which time VC sessions are conducted. The carefully designed scaffolding and assistance provided by teachers and mentors play a significant role in this implementation cycle. The process starts with inspiring students to ask meaningful questions driven by their genuine curiosity about real world phenomena. This leads to teacher-guided, student-focused investigation of those questions through various resources (e.g. media elements, textbooks) and hands-on experiments. Next, through different activities, students create new understanding and knowledge by making connections and theorizing significant thoughts based on prior experiences. Student-generated new knowledge is then shared within the learning community, including fellow schoolmates and teachers. Within this implementation cycle, e-mentors interact with students via VC or other technology in each stage.

Finally, evaluation (Stage 5) of student learning is conducted for both formative and summative purposes. Information collected in Stages 4 and 5 also shape the design of subsequent inquiry projects, which goes back to Stage 2, thus starting a new cycle. For example, based on students' written reflections about the bear project, we have designed our next project focusing on gemstones.

Although details of the research context (e.g. students, mentors, school) are described in the "Method" section, in the following paragraphs we illustrate, using the bear project as an example, how IBLE is implemented in this study. Throughout the project, two e-mentors have interacted with the students via VC and email. Such e-mentor/student interactions have been on a whole-class basis considering the amount of work required for the e-mentors.

In Stage 1, we identified an overarching theme for the semester: "How does understanding multiple perspectives shape the way we live in the world? In what ways does diversity shape our understanding?" In Stage 2, we brainstormed ideas considering the most challenging curriculum topics in math and science (e.g. 2D/3D shapes). Realizing that grizzly bears was a hot topic at that time because several bear attack incidents happened in the region and were covered in various media, and considering that one e-mentor had expertise on bear tracking with Global Positioning System (GPS), we designed the first inquiry project for students, choosing bears in the eastern slopes of the Rockies as the focal point. The project involved embedding math and science curricular activities (e.g. 2D/3D shapes) in current social and cultural affairs. In Stage 3, we planned three VC sessions, two for e-mentors to share their research and another for students to present their own research results. We also scheduled guest speakers from a zoo to talk about human/bear interactions.

In Stage 4, teachers initiated the implementation process, directing students' interests and their formation of the questions through different activities ranging from reading newspaper articles to watching videos. Teacher guided discussions led students to realize that the grizzly bear issues are connected to social, economic, recreational, scientific, agricultural, environmental, political, ethical, ego-centric, educational, medical, ecological and technological aspects of our world and hence needed to be examined through such multiple perspectives.

Interactions with e-mentors via VC and email also helped focus students' thoughts on the issues. The VC session was conducted, allowing the e-mentor to discuss her research of tracking bears using GPS to explore bears' habitats. She demonstrated how professionals conduct studies of bear movement in the Eastern slopes of the Rockies and included a genetics/gene pool game to stress the importance of biodiversity for the health of any species. This initial VC session was mentor-driven while teachers acted as facilitators in class to encourage participation and maintain classroom control. After this VC session, students wrote reflections about their experience and such information was used to direct the approach to subsequent VC sessions in relation to current and upcoming classroom activities. Sample reflection questions included:

- Overall, how do you feel about this videoconferencing session with [the e-mentor]?
- Which parts of the videoconferencing did you enjoy? Why?
- [The e-mentor] talked about using GPS tracking bears and how GPS works. How do you find that relates to your math or science learning? If possible, please give examples.
- What can make our next videoconferencing session more interesting/useful to you?

Later, students researched the topics in depth, gathered and shared information, identified issues, key concepts and ideas for deeper explorations. They discussed issues around biodiversity with scientific understanding through extensive research and critically analyzed information presented (e.g. media stories) from a number of perspectives (e.g. hunters, conservationists, farmers, and bears themselves), which led to an important connection between biodiversity and positive body-image and uniqueness. During this process, we also provided students with modified bear tracking data based on real GPS data. Working collaboratively to examine different bear habitats by analyzing the data and interpreting the results, students used mathematics (e.g. effects of dimension changes in related 2D shapes and 3D objects in solving problems) and science (e.g. biodiversity). See Appendix for part of the bear project.

Next, we provided various sharing opportunities, one of which was the third VC session where students became active leaders in VC and presented their research results to the e-mentors. The e-mentors critiqued student work and offered further insights into the curriculum topics/key concepts, connecting with the e-mentors' own research and real life applications. Students' enhanced understanding further inspired them to apply the newly generated knowledge by writing recommendation letters to the provincial government, lobbying a protection act for grizzly bears. The responses from the government officials (e.g. Premier, Minister of Environment) were highlights for students, allowing them to see how learning was connected with their life and how they could contribute to public policy and shape the world they live in. In the next phase, students were guided to synthesize and reflect on their learning.

In Stage 5, a teacher-designed midterm and final examinations were among many ways we assessed students' learning. Additionally, a culminating "Night of the Notables" was conducted where each student had to act as a famous mathematician/scientist. Visitors, including parents and students in other classes, asked questions and provided written feedback, which was also used to evaluate learning.

Research questions

Aiming to examine the effects of IBLE on secondary students' mathematics and science learning, we have implemented the model in a rural school. Although only math classes were involved in this rural school due to administrative limitations, our project—from data collection, to inquiry project design and implementation, to e-mentoring topics—nonetheless reflected an emphasis on students' learning of both math and science. Specifically, the following research questions guide this study:

1. How does the experience in an IBLE affect rural students' learning of math and science? Specifically,
   a. Does the overall learning experience in an IBLE environment improve rural students' achievement in mathematics as demonstrated in test scores?
   b. In what ways does the overall learning experience in an IBLE environment impact rural students' affective development in math and science?

   This overarching question seeks to gain information about overall effectiveness of the IBLE model, with the first question testing the gain effects of student math tests, and the second focusing on student beliefs, understanding of math/science, and career awareness.
2. What are the challenges of establishing an IBLE environment in a rural context? By identifying challenges, we can diagnose problems associated for development of guidelines for future implementation.

Method

This study used a mixed method approach for collecting data, focusing on affective (e.g. student beliefs, motivation, awareness) and cognitive outcomes (achievement). Adapting the concurrent nested strategy where an experimental design was embedded within a case study, this approach allowed for insight into varied perspectives, thereby answering different questions and drawing on all possibilities. Further, the concurrent structure of this study in collecting data simultaneously provided a broader perspective on the phenomena, with the qualitative data helping to describe aspects that quantitative data alone could not address (Creswell 2003). The predominant method that guided the research was the case study examining how rural students' experiences in an IBLE environment impacted their affective development and identifying the challenges in the implementation process. Given less priority, the quantitative method was nested using a pre-test-posttest quasi-experimental design that investigated the impact of IBLE on students' achievement scores.

Participants and context of the study

Participants

Three grade-eight math classes, taught by the same teacher, in a rural school participated in this study: one treatment group of 26 students and two control classes comprised of 41 students (13–14 years-old). Students' interviews and class observations at the beginning of the project provided information about the classrooms and students, hence the context of this study.

In this school, traditional teaching approaches were the norm; teaching and learning usually consisted of lecturing from the front of the room, repetition, and homework. Although assignments were not engaging, students were anxious to get down to the work itself and eliminate the verbiage. While most of the students had an appreciation for the general importance of math and science, and the role it might play in their careers, it was difficult for them to perceive the relevance of their actual assignments and work to their daily lives. It brought to mind the concept of "drudgery" with its connotations of drill and practice teaching and rote memorization. The role of inquiry-based and hands-on learning in this situation appeared to be minimal in math and science.

These teenagers tended to have many responsibilities and activities outside of school, along with travel time to and from school, therefore they wanted a break from homework. The amount of homework associated with an assignment or project played a major role in how it was enjoyed by these students. The following student comment exemplifies their thoughts on this issue.

> (I didn't like) anything we had to take home to do, because I really don't like homework. Because I'm like really, really busy so it would mean that I have to stay up later. [S3]

Part of the motivation to "get to work" in class was to complete assignments within the class time to avoid homework. Many students living on farms, particularly with animals, had extensive chores and responsibilities relating to their locale. They also felt disadvantaged by the lack of access to teachers before and after hours for help. Students taking buses found it difficult to attend math-help sessions beyond school hours, for additional help, or even to pick up required materials.

Another characteristic of these students was the diverse phenomena and relationships within each student's home life that affected their ability to do homework. The home environment was not always conducive to completing homework or getting adequate support. All of these students sought support and help with homework at home; familial involvement was deemed important and valuable by those who received that support. Those who did not have the support were also restricted from getting assistance from their friends through direct means, largely because of distances required to travel between homes in rural areas. Peer support for homework was often compromised because of isolation, and even in town, students felt isolated from other learners.

Technology access and use at home was inconsistent amongst students and these disparities created a barrier for virtual communication and homework support. While one student was using webcams to communicate with family and friends, many had no home Internet access. Computer literacy was perceived to be an urban characteristic.

Two female scientists/mathematicians, who were PhD students enrolled in engineering programs, were involved as the e-mentors. They had extensive backgrounds in math and science and volunteered for this project because of the opportunity to make a difference with students. The following interview excerpts described e-mentors' perceptions of their engagement in the project.

> I have truly enjoyed this project. Even though the last 6 months have been very busy academically for me, I highly value the opportunity to participate in the project. It is very rewarding to work so closely with experts in education. This project has allowed

me to be creative in the development of a series of VC lessons and has provided me with a tremendous amount of feedback on what is effective for VC learning. [interview, mentor 2]

It has been exciting to play a large role in the development of this unique outreach program. I am a strong believer in inspiration role models can provide to people of any age. Science and math are commonly stereotyped as difficult, esoteric subjects and anything that can be added to the curriculum to increase a student's interest or to make the subjects more appealing, is of value. Increasing awareness about careers that require a science and/or math background gives students a sense of the many different ways they can use the subjects in their futures. [interview, mentor 1]

Data and analysis

Both quantitative and qualitative data were collected at the same time, and later integrated to interpret overall results through statistical and thematic analysis. Quantitative data consisted of student paper-based academic tests (teacher-designed) including a pre-assessment (treatment group only) and the final examination (treatment and control groups). It is worth noting that although this pre-assessment was not conducted for the control group, students' final math grades in the previous year yielded no significant difference between the treatment and control groups, which therefore indicated the compatibility of the two groups for meaningful comparisons of their final marks.

Due to administrative constraints, we could only use these teacher-designed tests. The items for both pre-assessment and final examination were of a similar nature and included fill-in-the-blank, numeric calculation and word problems. An example of word problem was: "A scalene triangle has a perimeter of 36 cm. One side of this triangle is 3 cm longer than the shortest side and the longest side is one cm more than twice the smallest side. Find the length of each side." Descriptive analysis was performed for two sets of scores: pre-assessment tests and final grades. An independent *t*-test was conducted on final grades between treatment and control groups to determine if there was any significant difference between the mean scores of each group. Additionally, a paired-sample *t*-test was performed on pre-assessment test and final grades for the treatment group to examine if there was any significant difference in their scores before and after learning in an IBLE environment.

Qualitative data consisted of interviews of students, their teacher and e-mentors; detailed field observation notes; teacher's reflective journals; videotaped VC sessions; and student written assignments. During the term, we held regular meetings with the teachers, e-mentors and teacher educators to discuss and revise IBLE and the design of activities. Detailed meeting minutes were also part of the qualitative data. A total of nine students were interviewed either individually or in pairs at the beginning, middle, and the end of the semester. These nine students were selected because they reflected the full spectrum of academic achievement. Semi-structured interviews were conducted with a list of questions that served as a framework, but often went beyond the initial questions to explore students' perceptions. The reason for choosing a relatively small number of students to interview was twofold: (1) it would allow us not only to build student trust and confidence but also to conduct an in-depth analysis; (2) since interviews were only allowed during school hours, reducing the number of interviewed students would minimize interference in their academic routine.

The analysis for this paper focused on the student interviews and field notes, although other data provided contextual information. We first classified the data and generated initial codes independently from research questions and conceptual framework. Drawing on the literature of inquiry and rural education allowed us to develop our coding system to probe the impact of the IBLE environment on students. The inter-rater agreement was 82%. These initial codes were then compared, discussed, and continued to be revised during our interaction with data until mutually agreed themes were developed. Grouping the data under different codes allowed us to see different patterns and themes emerging. These different themes were interpreted within the broader social context of the school. To ensure reliability and accuracy, we employed strategies including the collection of different forms of data for triangulation, analyzing data independently by three researchers, looking for extreme cases, and paying particular attention to negative evidence (Miles and Huberman 1994).

Results

Effects on achievement

To address the research question 1a, quantitative analysis of test scores was conducted to examine the effect of IBLE on students' math achievement. Comparing the final exam grades between treatment and control groups, the independent t-test showed no significant difference between the treatment group ($M = 97.35$, SD $= 28.55$) and the control group ($M = 85.4$, SD $= 24.54$), $t(65) = 59.03$, $p = .056$, see Table 1. Considering the uneven sample sizes between treatment and control groups, a corresponding non-parametric procedure (i.e. Mann–Whitney analysis) was also performed. This (Mann–Whitney $U = 404.5$, $p = .098$) yielded a similar result to the t-test, supporting the original findings.

Then we focused on the treatment group by conducting a paired-sample t-test to examine possible treatment effects. When the pre- and post-tests were analyzed, a significant difference was identified (pretest: $M = 57.76$, posttest: $M = 67.75$), indicating that students' achievement was significantly improved from pretest to the posttest: $t(25) = 3.54$, $p = .002$, see Table 2. But the results above between treatment and control group indicated that this change might be caused by changing of test items.

Effects on student learning

To answer research question 1b, qualitative data were analyzed to explore how IBLE impacted student math and science learning, focusing on affective development. Three

Table 1 Final grade comparison between control and treatment groups

	N	Mean (144 points)	SD	t	Sig.
Control	41	85.4	28.55	59.03	.056
Treatment	26	97.35	24.54		

Table 2 Treatment group pre-assessment test and final grade comparison

	N	Mean (%)	SD	t	Sig.
Pretest	26	57.76	19.67	3.54	.002
Posttest	26	67.75	17.38		

salient themes were identified, indicating a resultant effect on the students' confidence and interest in learning the subject matter, the relevancy of science and math, a change in their perspective of the roles of scientists and mathematicians, and awareness of career possibilities. Table 3 provides examples of paired data from earlier and later in the study to demonstrate the kind of changes that resulted from this experience.

Impact 1: improved engagement and motivation

Foremost among the students' affective responses to learning math and science in the IBLE environment was a salient theme around improved engagement and motivation. In the interviews, most students identified a preference for the inquiry-based approach, citing increased interest and enjoyment in doing the work. They were motivated by moving away from a traditional lecture style, allowing for more hands-on work that could proceed at an individual's most comfortable pace. Following quotes from students exemplified these:

> More projects. They're funner. And I get more out of them than I do from the worksheets. That's what I've noticed. [post-interview, S8]
> I like learning about the world around us, that sort of stuff, I just find it a lot more interesting. Well sometimes you do have to work pretty hard, but it's a lot better. [post-interview, S7]

Demonstrations involving visual aids were most appealing, and project work and group work were also favored. The students desired more interactivity, which inspired us to modify both classroom and VC activities. For instance, an e-mentor changed one VC session from her presentation to a game-based mentor–student discussion. Students appreciated their teacher's gradual adaptation of the teaching method in line with inquiry-based approach. As the project progressed, students felt more confident in math: that it was getting easier for them, attributed by some to the change in teaching approach and increased support they were receiving from their teacher. Beneficial changes included an increase in collaborative work and in-depth explorations. Increased engagement was also reflected in student commitment to school work. The following field observation notes about the student CH and the teacher interview about the student BJ served as a testament for such changes.

> CH is really shy and considered by the teacher, 'a low achiever'. After finishing her group bear project, she commented that she liked the project with many interesting questions: "lots of information can be found [through this project], like older bears with cubs move a lot more [than younger ones]. Maybe because they know the area better, can feel comfortable to travel. When grizzly and black bears overlap, what would happen?" (Field notes, May 8, 2006).
> Math is not BJ's favorite subject. But [for this project] she is the only one that handed everything in on time and she had stuff written down. Now THAT'S very good for her. Because she was on my list to get assignments in and she's always very reluctant to hand in work. [post-interview, teacher]

Simply using VC via broadband technology provided students with a new perspective as demonstrated by the following student interview.

> [The VC] just opens your eyes, that there's this new technology going on, and you can't always stay chalkboard and classroom forever. It's good that we're doing it

Table 3 Sample codes to probe the impact of the IBLE environment

Impact	Code	Pre-data (e.g. interview/field notes)	Mid- and post-data (e.g. interview/field notes)
1. Engagement & motivation	Engagement	• Teacher-centered, lecture based teaching e.g. *T*: because I have my curriculum to follow and I need to cover these concepts, I tend to spoon feed kids in math [teacher pre-interview] *S*: in math class, the teacher usually talks first and then we do boooooooooooring worksheets [student pre-interview]	• Engagement reflected through enjoyment, better understanding e.g. *S1*: more projects. They are funner. And I get more out of them than I do from the worksheets [student post-interview] *S2*: The worksheets are easier, but the projects help me learn [student post-interview]
	Confidence	• Many students have low confidence e.g. *S1*: I do not like math and have never had an interest in it because I kind of struggle with it and sometimes it does not make sense [student pre-interview]	• Increased confidence, self-esteem e.g. *T*: I see a lot of change in the student attitude and the perception of math and science. I really think [the project] helps build some self esteem in students. They may not achieve in mark wise, but they feel better about coming to class and about being here [post-teacher interview]
2. Relevancy of math/science to student lives	Daily life	• Superficial understanding (e.g. shopping) e.g. *R*: how do you use math in daily live? *S1*: shopping…you need to know how to subtract from the top of your head *S2*: I don't really go to the bank often. I don't think I've had to use math outside of school for a long time. [pre-interview, students]	• Easily relates math/science to daily life: e.g. *S1*: This weekend, we were spraying our lawn and we had to do some really weird math to know how much we should use and how we should mix it, and I guess you need that just for everyday living [mid-interview, student] *S2*: I think about [science] more…I got home, saw my dog and thought, she's probably a pure bred poodle [student post-interview]
	Multidisciplinary application	Math, science are isolated subjects e.g. *S*: I do not see any connection between what we are learning in math right now and other subjects [student pre-interview]	• Many appreciate the connectivity among different discipline e.g. *S1*: It's sort of like having a science class in math [student post-interview] *S2*: it makes me realize how some subjects go together [student mid-interview]

Table 3 continued

Impact	Code	Pre-data (e.g. interview/field notes)	Mid- and post-data (e.g. interview/field notes)
3. Roles and careers	Images of Mathematicians/ Scientists	* Stereotyped image: e.g. male with beard, wizard of math, white lab coats e.g. [student pre-interview] *R*: Can you describe what a mathematician/scientist looks like? *S*: I don't know… A person who's always writing things down? * description limited to appearance	• Gender: mathematician/scientists can be male or female • Going beyond surface description (appearance) to personality traits e.g. *S1*: Now I see [mathematicians/scientists] actually going out into the world helping people *S2*: [mathematicians/scientists] have to be really dedicated and never give up, they are excited to keep on going [student post-interview]
	What they do	* Confusions about what they do [student pre-interview] *R*: What do you think a mathematician does? *S1*: Study math *R*: Such as? *S1*: I don't know… *S2*: I think they work with numbers and figure out stuff with formulas	Broader view of what mathematician/scientists do e.g. [student post-interview] Now I see [mathematicians/scientists] actually going out into the world helping people
	Career	• Students have misconceptions about mathematicians • Stereotyped notions about careers related to math/science e.g. *S1*: My 3 year old niece can be a mathematician because she's like "1, 2,…" [student pre-interview] *S2*: My math role model is my grade 2 brother because he is really good at math [student pre-interview] *S3*: I want to be a vet because I really like animals and it's pretty cool. But I do not think it needs math…maybe a little bit science [student pre-interview]	• Math is building blocks for careers • Rethinking about career choices related to math/science • Become open-minded about career possibilities (e.g. Changing from knowing what career they wanted to being unsure because they were aware of more possibilities) e.g. *S*: Even going to the VC, listening to [e-mentors] taking about her experiences in university, just shows how many [math-/science-related career] choices there are out there. It's really huge [student post-interview]

R researcher, *S* student, *T* teacher, *M* e-mentors

> now, because then you're used to it when you're older, and you're not all behind, like my parents. [post-interview, S2]

Many students enjoyed learning using VC, as it offered a break from the routine of their regular classes and added a new dimension. Students welcomed the new perspective of the e-mentors, indicating even from the beginning of the project that they would be energized and excited to work with role models while being exposed to new technology. This enthusiasm was consistent among students of varying achievement levels. The following comments extracted from students' interviews exemplified their feelings about the project.

> It's not like normal math class. I actually learned more [in this environment]. It's not as boring as reading from a textbook, or learning off the overhead. It's like you're actually visual, visible, talking to somebody who actually learned it and is experienced with it. [mid-interview, S3]
> I like doing videoconferencing. I'm glad it's our class. A guest speaker's good having face-to-face. But videoconference is more exciting. [mid-interview, S6]

The interactive VC presented an opportunity for the students to hear from experts/e-mentors/role models, as expected, but also to be heard. Sharing their projects and then being critiqued by the e-mentors allowed students to discuss their opinions, and the students appreciated that they weren't being lectured to continuously, as many anticipated to be. Further, the students developed a broader view about role models than we, as researchers, initially envisioned. Originally only the e-mentors were introduced to the students as role models. To our surprise, students also considered the researchers, a university professor and a graduate research assistant, as role models. Interacting with students via ongoing formal and informal interviews, and bi-weekly class observations, we established rapport with these students. They were surprised but happy that we wanted to hear from them, because it indicated that we were genuinely interested in them and their thoughts, not just the subjects to be learned. The fact that we took their ideas and integrated them into refining the curriculum activities and teaching practices demonstrated how much we valued their opinions as demonstrated in the following observation note, student and e-mentor interviews.

> Today students presented their group projects about bears to us. As we [e-mentor and the first author] commenting on and critiquing their presentations, students were inspired and actively asking questions. The atmosphere became more relaxed. DH, a student with Oppositional Defiant Disorder (ODD) who usually played with his lego at his seat, was very attentive today. He asked: "why do the younger bears go close to water and older ones go up to the mountains?" "Is that really a circle or is it an oval?" After class, he told us that he really liked this discussion with experts, "because it really made me feel special." (Field notes, May 23, 2006).

This mutual interest resulted in a more open, attentive, and responsive learning experience.

> It was like [e-mentors] care, they notice you, they actually ask questions. They're interested in you, and not just talking. [mid-interview, S1]
> The project strengthens my conviction that mentoring is an important and valuable tool to promote learning…It is particularly important for young people to be exposed to many different ideas and given an opportunity to discuss their own ideas with

> people both in and outside their classrooms. This increases their self-confidence and makes them more comfortable sharing their thoughts. [post-interview, e-mentor 1]

The overall impacts on the students' learning were evidenced in students' (1) increased enjoyment of school work because of the new diversity in teaching praxis and hands-on creative projects, (2) raised interest in math and science because of personal engagement through interactive questioning, discussion with e-mentors and the excitement of using of new technologies in the classroom, and (3) improved confidence and self-efficacy in math learning, because of more engaging methods of instruction and support from the teacher, based on the inquiry approach.

Impact 2: broadened understanding of the relevancy of math and science in students' lives

Another noticeable impact on students was their expanded recognition of math and science in their lives. A better understanding of the relevancy of math and science resulted in an increase in student interest in these areas. Getting further in depth into the topics and seeing how they affected our everyday lives heightened student motivation in learning of math and science.

> This weekend, we were spraying our lawn and we had to do some really weird math to know how much we should use and how we should mix it, and I guess you need that just for everyday living, you need math. [mid-interview, S7]
> [This experience] made me realize where math is, and how much there is in the world. [post-interview, S3]

Additionally, the teacher noticed that students felt more confident in these areas, which in turn, she felt, boosted their self-esteem.

> I see a lot of change in the student attitude and the perception of math and science. I really think [the project] helps build some self-esteem in students. They may not achieve in mark wise, but they feel better about coming to class and about being here. [post-interview, teacher]

The overall experiences also increased students' awareness of multidisciplinary applications. For example, they were surprised and interested to see how much science was involved in what they considered "mathematics" projects. At the conclusion, most students appreciated the connectivity among different disciplines, naturally math, science and technology, to the extent some students could imagine learning them together instead of as disparate subjects.

> I'm learning more about technology and science than I normally would in math class. It's sort of like having a science class in math. [mid-interview, S8]
> [This experience] makes me realize how some subjects go together, so if I like one subject, I can like them both when they're integrated… Math and science are perfect together. [post-interview, S7]

This increased awareness of the relevancy of math and science in students' lives allowed students to make meaning of what they were learning at school while relating it to other aspects of their lives. This newfound awareness was highlighted in the understanding that math and science are interrelated and do not have to be considered as disparate disciplines, as they are often presented at school.

Impact 3: increased awareness of roles and careers in math and science

Both observations and interviews provided ample evidence that students' experience in the IBLE environment resulted in their enhanced understanding of roles of mathematicians and scientists. For example, at the beginning, career stereotype were prevalent as students could only provide very limited descriptions of what a mathematician might do. Towards the end, students came away with a broader view of the roles of both scientists and mathematicians.

> I figured a mathematician or scientist would just be figuring out [formulas], but now it's kind of different, because I know they do a whole range of things. [post-interview, S6]
>
> Now I see [mathematicians and scientists] actually going out into the world helping people. [post-interview, S9]

Conversing with female scientists/mathematicians dispelled gender and personality stereotypes of these roles, with many students in the post-interview describing a typical scientist or mathematician as "normal—could be anybody".

> Before it's like scientists are the guys that stand in a workshop or whatever all day in big coats and crazy hair. [This experience] gives you a different idea of what scientists are like. [mid-interview, S2]
>
> She [e-mentor] doesn't look like a nerd, like I've always thought. [mid-interview, S6]

Many students showed a greater awareness of how science and math concepts might be applied in future careers. The greatest increase in awareness was in the lower achieving students, especially if they could foresee relevancy in their own planned career. The impact was much stronger when a personal connection was evident than if there was no personal relevancy. The highlight of the bear project for one student was making the bridge between (GPS) technology described by an e-mentor, and foreseeing potential use in her career. Some students were able to link the e-mentors' presentation to their future career.

> The third VC session was with an e-mentor in physiology. She talked about knee joints and differences between physiology and anatomy. She also discussed different career paths including biochemistry, anatomy and physiology. The e-mentor shared her research that involves the use of ping pong balls and pig knees to track the motion of the joints and how they use math. MR and DJ, who wanted to become police officers and were interested in forensic science, were very attentive to the presentation. After the session, they told us that they are interested in "figure[ing] out how knees work would help us know how people died. You need to know how they die in order to find suspects." (Field notes, May 2, 2006).

As a result, students' increased awareness of roles and careers in math and science opened up choices and ideas for their career planning and navigating future schooling. In short, we found that IBLE facilitated students' learning as they (1) displayed a broader context of understanding of what scientists and mathematicians actually do, (2) dispelled previously held stereotypes including gender biases, and (3) considered how math/science might be useful in their own careers of interest. When students could make a connection with the math/science topic they were learning about and its potential use in their planned careers, it increased their attentiveness and personal interest in the topic.

Challenges

The second research question sought to identify challenges in the process of creating an IBLE environment in order to develop useful guidelines for future implementation. These challenges revealed some students' lack of knowledge of current math and science use in existing professions (e.g. biologist, veterinarian), the technical quality of VC, camera/monitor use and the set-up logistics, and the students' physical comfort during the sessions.

Despite the general broadening of understanding of the role of math and science, some students still lacked realistic expectations of what specific careers entailed, as exemplified in the following student interviews, and this seemed to pose a barrier to finding relevant ties between the career and science/math curriculum.

> Marine biology doesn't need a whole bunch of math, I don't think it's going to need equations. [mid-interview, S7]
> I never really wanted to go into a career as a math person. I'm leaning more to a career in animals. [post-interview, S5]

The quality of the technical experience was the most important condition in determining the quality of students' VC experience. There was little tolerance for technical difficulties in the classroom. Technical difficulties ranged from minor sound delays to frozen frames to complete loss of contact. Trying to maintain a stable connection was the greatest challenge. At best, the technology glitches were just a slight annoyance, but in worse cases, they have shut down a normal flow of conversation. On a couple of occasions, technical glitches during the VC sessions became a vital barrier, negatively affecting the students' perception of their learning, particularly when the audio failed. In fact, poor audio quality forced us to reschedule a VC session twice. Poor video quality in one session distracted the students, but audio issues, where logistics required students to speak loudly across the room into one microphone, actually discouraged some students from participating fully in the session. One student decided it would be too awkward to offer his comments in class. Students also were impacted by the spatial arrangement of the VC room, indicating better visual ability for both e-mentors and students would improve VC experiences.

> Like if [the e-mentor] could see all of us, it'd be better, because some kids could be goofing off and for all she knew, they could be hopping out the window and running away. [post-interview, S7]

Physical comfort also contributed to the learning environment, which was particularly evident during the VC sessions. The increased physical comfort in the VC sessions with better chairs and tables allowed students to have an enjoyable learning experience.

Another difficulty was camera and monitor limitations that restricted whom or what could be shown on the screen. Such limitation affected the dynamics of the interaction and created an experience that was frustrating for the participants, especially the presenter. For example, switching between the different modes of operation or camera views during VC was a troublesome procedure, often causing enough distractions to disrupt the flow of a meaningful dialogue. Sometimes, important information conveyed through body language and facial expressions was lost in the process of toggling between wide shots and close-ups. Even with high quality cameras and large monitors, the e-mentors still had difficulty seeing the audience clearly and in gathering any immediate feedback on their presentations. This underscores the importance of facilitators on site to monitor the learning process and to provide any necessary clarification or details.

For the teacher, a big challenge was to set up the room for VC with regards to both technical skills and the time needed, exemplified by the following teacher comments.

> The biggest barrier is it's so time consuming to set up in class. That, or have everyone crowd around my computer. I've got to set everything up and it's just not easy to do: we have to change the room with another teacher, go to a different room, set up first, clean everything up after, put everything away. But I have a class right after so it's really challenging. [post-interview, teacher]

Discussion

This paper discusses our implementation of IBLE in the rural context which was the second phase of a 3 year project. Elsewhere (Li 2007) we have described the first phase of implementation in two grade 9 urban classrooms involving two math and science teachers, a humanities teacher and their students. This study contributes to the knowledge of inquiry-based learning in rural education and new technology in schools. Focusing on rural students, a traditionally under-researched population, this empirical investigation adds significantly to our understanding of how to serve these students better and how to best use our resources to enhance learning. Considering that affective development is vital in student life and often is a long time endeavor (Martin and Reigeluth 1999), an important contribution of this work is the finding that learning in the IBLE environment has positively impacted students' affective development as reflected in their increased motivation, broadened understanding of math and science, and increased career awareness.

The most significant contribution of this study lies in the successful implementation of IBLE in a rural setting, thereby demonstrating a feasible model of inquiry-based learning with e-mentoring. The results of this study show that VC-supported e-mentoring was at least as effective as regular mentoring. e-Mentoring through VC with no travel required may allow the mentor activities to be expanded from a few schools to many schools in any location with broadband technology. The increased broadband connectivity around the world enables us to overcome geographic challenges and provides mentors to students who would not otherwise have them. This therefore directly addresses the limited-resources issue in areas such as rural and marginalized regions.

A review of the existing research reveals an assumption that is implicit in much of the literature: the implementation issues and challenges associated with using VC in schools do not matter enough to be the focus of analysis. Limited studies (Carpenter 2004; Pemberton et al. 2004; de la Garza 2006) have examined implementation issues related to VC, but none have focused on VC-supported e-mentoring in an inquiry-based learning environment. We, however, believe that implementation deserves researchers' serious attention because our results indicate how these issues have impacted the type of student engagement. Technical problems are particularly irritating to students, with less tolerance for audio problems than video problems. Consistent with previous work (Pemberton et al. 2004), other technical issues like the limitation of camera and monitor scope hinder student engagement in interaction. Successful establishment of IBLE also depends on physical comfort of students and time/technical demands for teachers. Challenges identified in this study highlight the importance of teacher support: from strong administrative leadership (hence to provide a warm, supportive environment), to focused training and practice of VC for teachers (to learn appropriate strategies), to quality technical support (so teachers can concentrate on the pedagogical issues and content instead of troubleshooting).

Due to administrative constrains, we had to use teacher-designed tests to assess achievement and our analysis showed no significant difference between the treatment group and the control group, demonstrating that the treatment group at least did no worse on typical measures of learning. Elsewhere (Li 2007) we have described our phase 1 work of urban students and, based on the data collected two years after the project concluded, have found positive long-term effects on their achievements and confidence in math/science. Although unable to obtain the longitudinal data for rural students, we suspect that IBLE will have similar positive long-term effects. Further, we argue that students in the treatment group present advancements in other areas that are often not focused on but important nonetheless; however, we cannot demonstrate those advancements in simple measures because as of yet these measures do not exist. Such advancements focus on ‘extended learning’ that support positive transfer and long term effects. For example, students working in IBLE have developed the habits of mind and an appreciation of an authentic pursuit of new knowledge that prepare them for future learning. Scholars (Bransford and Schwartz 1999; Schwartz et al. 2007) have demonstrated that conventional standard assessments and one-shot task performances cannot measure such hidden values of educational experiences.

Previous research (Gati and Saka 2001; Germeijs and Verschueren 2006; Witko et al. 2005) has shown that adolescence, starting in the junior high years, is a critical time for students to think about career directions. These authors argue that course selection could affect their chances of being accepted into a program of their choice in post-secondary institutions and subsequent career directions. In order to make informed choices and dispel biases about careers, students need exposure to diverse career options, in which mentoring is one way for students to learn about different occupations. Our study shows that students’ learning experiences in IBLE were helpful for providing insight about career opportunities in math and science-related fields, and generating excitement about new career directions. This finding is consistent with other studies that show how mentors can encourage students to consider a career in science, though they had no interest in science-related careers prior to the mentoring experience (Packard and Nguyen 2003).

In this study, although stereotypical notions of mathematicians and scientists were not completely dispelled for some students, the e-mentoring experience facilitated well-rounded notions of who could be a scientist or mathematician. This was particularly important for the students who had few or negative experiences with mathematicians or scientists in the past, since positive interaction with the e-mentors allowed them to imagine how they could follow a similar career path. This confirms that interaction with scientists can “provide an additional source of expert information, provide a window on an example of real science as it is being practiced, and even help to break down certain myths and misconceptions” (Kubicek 2005, p. 53). Positive mentoring experiences with mathematicians and scientists who have well-rounded lives can add perspective, especially since many students tend to hold negative opinions about these fields (Bennett et al. 1998).

Some students reported that interacting with e-mentors increased their confidence in math and science. They noted that having the researchers and e-mentors work with the teachers resulted in highly relevant and interesting units of study. Additionally, the students appreciated when they were consulted about the learning experience because it made the learning more applicable to their lives. Knowing that their ideas were valued and utilized motivated students and gave their confidence another boost. This suggests that rural learners seeing learning as a social activity and responding best to a “warm, supportive environment”. The iterative redesign approach allowed lessons to be tailored to student needs and interests, another motivating factor.

Conclusion

This paper discusses our implementation of IBLE in a rural context which was the second phase of a 3 year project. Our implementation in an urban school (as delineated elsewhere, Li 2007) and subsequently rural classrooms have allowed us to develop and improve the IBLE, to understand the potential and the limitations of the model, and to articulate further directions for our research and design. In the following, we highlight two design considerations for IBLE that may be most accountable for its effectiveness and conclude with educational design guidelines and future directions for research.

Systematic design & scaffolding for VC supported e-mentoring

While mentoring may be a common practice and its benefits are well acknowledged, typical mentoring programs often have limited teacher involvement or curriculum integration (Rhodes and DuBois 2006; Bernstein et al. 2009). As well, traditional guest speaker approaches tend to become isolated events. Different from either of those approaches, IBLE emphasizes the systematic design of the environment where e-mentors work continually with teachers to enable an organic integration of e-mentoring and curriculum activities. All experiences were designed with a thoughtful consideration of e-mentors' expertise and curriculum contents, which therefore providing students holistic views about the concepts learned from diverse perspectives. Because e-mentoring occurred over a semester, students had the opportunity to reflect on prior VC sessions and ask the e-mentors deeper questions over time. If a guest speaker were brought into the classroom as an isolated event, students could not have had extended time to reflect: their questions and comments are not as thoughtful as when they have sustained access to a mentor, a finding which confirms the previous research that students benefit from mentoring opportunities that occur over time more than single experiences (Packard and Nguyen 2003).

In a similar vein, IBLE demands consistent e-mentoring in implementation (Stage 4) of inquiry projects. e-Mentors worked with the students in all phases of the inquiry projects, from initializing questions, to investigating, to sharing, while providing scaffolding to facilitate inquiry. Throughout each phase, e-mentors provided support in various ways but gradually decreased their involvement while students progressively took on more responsibilities, allowing them to see deeper levels of complexities and different aspects of the issues related to the inquiry projects. For example, the bear project was initiated through adult-led activities (e.g. teacher bringing newspaper articles and VC with e-mentor). Moving to the "investigate" and "create" phases, students took more ownership of their learning as evidenced by their various initiatives (e.g. bring new resources to class). One incident occurred during the "create" phase, when some students identified a website lobbying government to protect grizzly bears and autonomously brought this idea to the teacher and later to e-mentors, actively seeking for advice in the "share" phase. This led to a letter writing campaign where they wrote letters to the government officials regarding bear conservation based on their research.

We found the systematic design with continued e-mentors' involvement to be extremely important, as explained by the teacher: connecting students with e-mentors in an extended period of time while integrating curriculum allowed students' in-depth understanding of e-mentors' scientific research in relation to their learning of specific curriculum contents.

Engaging students in guided inquiry

Inquiry-based learning places authentic problems and issues at the center, therefore engaging students in deep learning while allowing them to create a sense of ownership and helping them internalize knowledge (Choi and Lee 2009). For the development of IBLE, authentic, real world issues were collectively developed by teachers, e-mentors, educational consultants, and researchers, and placed in the center. These issues drew on current events with rich contexts, guiding learners to explore complex ideas and dilemmas that are directly linked to their life. The scaffolding and guidance provided by teachers and e-mentors is a vital component that should not be overlooked in each phase. Being exposed to and witnessing e-mentors' scientific research in action to solve real-world problems, students could build knowledge in more meaningful ways (Cullingford 2006).

In IBLE, e-mentors enlisted in each stage allowed a careful design and a continued adjustment of learning activities in order to closely align curriculum activities with real world applications in relation to e-mentors' research. In particular, e-mentors played an instrumental role in all phases of the Stage 4 via VC and email.

Implications for development and implementation

In this section we describe some development and implementation guidelines that focus on helping rural students. First, IBLE demands the establishment of a warm, supportive environment with carefully designed student-centered learning activities. The genuine care for students by listening to their voices and integrating their opinions into the design of curriculum activities nurtures more open, attentive, and responsive learning experiences. Engaging in novel activities can heighten students' interest and confidence because it is not only a welcomed interruption of classroom routine, but more importantly, makes students feel special. Although the idea that learning should be relevant and fun is not new, rural students in this study showed a strong appreciation for the animal examples given during the VC sessions. They also gave suggestions of other species to study for future exercises, not surprising given the amount of animal care in their lives.

Second, our study of developing and implementing IBLE underscores student learning preferences: (1) As discussed in the "Impact 1" section, students desired more interactivity which highlights that it is a key factor that contributes to successful learning, whether face-to-face or via VC. When provided opportunities to interact with others, students become highly engaged. (2) Bringing external experts as e-mentors can not only provide much needed resources and expertise for rural students, but also energize and excite them while exposing them to new technologies. This exposure to new technologies is important, particularly for such a group so that they do not feel 'left behind'. (3) Physical learning conditions should not be overlooked because they have an impact on successful learning. When technology is used, it needs to be integrated seamlessly into curriculum activities because technical difficulties can negatively affect students' learning experience, highlighting the need for focused training and practice in conducting VC.

Limitations of the study

This research has limitations. First, we used teacher developed tests to examine achievement gains; however, these tests might not fully reflect student learning in an inquiry-based environment and therefore may not be suitable to assess the impact of IBLE. Consequently, our result that the overall learning experience in an IBLE environment improves rural students' achievement in math as demonstrated in test scores should be understood with reservations. Future research is needed to ensure a close alignment of the quantitative assessment with the IBLE in order to truly examine the impact on student achievements. As well, alternative assessments that go beyond conventional standard assessments and one-shot task performances need to be considered in order to reveal hidden value of such educational experiences. Second, due to situational constraints, we were unable to invite teachers of other disciplines (e.g. science) to join us. Feedback from both the students and teachers recognized the interdisciplinary nature of science and math and the potential benefit of a multidisciplinary approach. This suggests that learners in future projects may benefit most by a more holistic approach, not only with regard to subjects, but also involving more diverse personnel. Last, although we used the student final grades of previous year as the benchmark to ensure the compatibility of the treatment and control groups, we did not conduct our pre-assessment for the control group. Future research should include pre-assessment data for both groups to ascertain the rigorousness of the quasi-experimental design.

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Appendix: Bear protection project (Part 2)

Scenario

There has been a significant increase in the number of bear and human encounters in recent years. Bears are a species with significant conservation concerns in North America and their population and habitat status are considered to be indicators of the health of ecosystems. You belong to a team of environmental specialists at Parks Canada, a government agency committed to protecting the country's natural and cultural heritage. You and your colleagues are currently involved in a special project—its main objective is to ensure the long-term conservation of bears in the province. New remote sensing tools such as GPS collars have been used to track bear movements and monitor mortality rates. Now the team finally has enough information to start analyzing.

Tasks

You and your team partner have been assigned to study one of the 5 bears: Mary, Scott, Snoopy, Katie and Duncan.

1. On the map, identify places where this particular bear has been spotted over the last two years. Plot these points on the map.
2. Calculate the average Latitude and average Longitude. Plot this point on the map. This will be the center of the circle that you will need to create for the next step (Question for you: why is that?).
3. Develop your *bear's habitat map* by creating a circle using the information you have: (i) Radius in *degrees*; (ii) Center of the circle.
4. Calculate the area of your bear's habitat (use Radius in km). Color this territory and label it as the "Bear Protection Area".

Reflection

After finishing the tasks, discuss your findings with other teams and compare your results. Write a report for the Parks Canada based on your results from this analysis and your discussions with the other teams. What suggestions do you have for Parks Canada?

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Qing Li is Associate Professor at the University of Calgary. Her current research interests include technology-supported learning, digital game based learning, and mathematics education. Dr. Li was a visiting scholar at the Massachusetts Institute of Technology (MIT) in winter 2009.

Lynn Moorman is an Assistant Professor at Mount Royal University and is completing a PhD in Education Technology at the University of Calgary. Her current research concerns spatial literacy, and the use of virtual globes in providing geographic context for STEM learning at the K-12 level.

Patti Dyjur is an Instructional Designer with the Teaching & Learning Centre at the University of Calgary, where she conducts workshops and provides consultation to faculty on issues relating to course design. She is currently working on her PhD in Educational Technology.