Canadian Journal of Learning and Technology
La Revue Canadienne de l'Apprentissage et de la Technologie

Volume 35, Number 3, Fall / automne 2009

Using Videoconferencing to Provide Mentorship in Inquiry-Based Urban and Rural Secondary Classrooms

Authors

Qing Li, Patricia Dyjur, Natalya Nicolson, and Lynn Moorman

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.
Email: qinli@ucalgary.ca

Patti Dyjur is an Instructional Designer with the Teaching and 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.
Email: pdyjur@ucalgary.ca

Natalya Nicholson is a Ph.D student in Geomatics at the University of Calgary.
Email: natalya.nicholson@pointgeomatics.ca

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.
Email: lmoorman@ucalgary.ca

Abstract:

The main purpose of this design-based research study is to examine the effects of an inquiry-based learning environment, with the support of videoconferencing, on both rural and urban secondary students' mathematics and science learning. An important aspect of this learning environment is the use of videoconferencing to connect classes with mathematicians/ scientists (as e-mentors). Specifically, the following two research questions guide this study: (1) In what ways, if any, does the inquiry-based learning environment impact student beliefs and learning outcomes? (2) What challenges emerge in the development of an inquiry-based learning environment with secondary students in both rural and urban schools? Using a mixed methods approach, this study focuses on two grade 9 classes in an urban school and three Grade 8 classes in a rural school. The results suggest positive effects of this learning environment on student learning of math and science. In particular, both urban and rural students showed significant gains in their achievement. In addition, students showed an increased interest and heightened confidence in math and science. As well, the results point to issues arising from the process, suggesting useful guidelines for the development of such environments.

Résumé

L'objectif principal de cette étude de recherche axée sur la conception est d'examiner les effets d'un environnement d'apprentissage basé sur le processus d'enquête et utilisant le soutien de la vidéoconférence sur l'apprentissage des mathématiques et des sciences auprès d'élèves du secondaire en milieux ruraux et urbains. L'utilisation de la vidéoconférence pour mettre les classes en lien avec des mathématiciens et des scientifiques (en tant que cybermentors) constitue un aspect important de cet environnement d'apprentissage. Plus précisément, les deux questions suivantes orientent la présente étude : (1) De quelle manière, le cas échéant, l'environnement d'apprentissage basé sur le processus d'enquête a-t-il un effet sur les croyances et les résultats d'apprentissage des élèves? (2) Quels défis émergent lors de la mise en place d'un environnement d'apprentissage basé sur le processus d'enquête auprès d'élèves du secondaire dans des écoles en milieux ruraux et urbains? Cette étude, qui utilise une méthode de recherche mixte, se concentre sur deux classes de 9e année dans une école urbaine et trois classes de 8e année dans une école rurale. Les résultats suggèrent que cet environnement d'apprentissage a des effets positifs sur l'apprentissage des mathématiques et des sciences par les élèves. En particulier, les étudiants des milieux urbains et ruraux ont affiché des gains significatifs dans leurs acquis scolaires. En outre, les élèves ont démontré un intérêt croissant pour les mathématiques et les sciences de même qu'une confiance accrue dans ces matières. Enfin, les résultats permettent également d'identifier certains éléments qu'il convient d'examiner relativement à ce processus et de suggérer des lignes directrices utiles pour la mise en place de tels environnements.

Introduction

The fundamental importance of science and mathematics is well recognized in our society. In the last decade, results from various international studies, including the Third International Mathematics and Science Study TIMSS 1995 and 2003 (Mullis, Martin, Gonzalez, & Chrostowski, 2003), the Evaluation of Educational Achievement (IEA), and the Program for International Student Assessment (PISA) (Gonzales, et al., 2004; Mullis, et al., 2000), show that North American students persistently lag behind students in many countries, especially Asian countries, in their math and science achievements. Complicating the issue even further, rural students are at a higher risk of leaking out of the science and mathematics pipeline because of low resource availability and poor visibility (Schoenfeld, 2002a). While many, if not most, rural schools have basic Internet access, they remain, as a rule, technologically impoverished (Li, Moorman, & Dyjur, 2008; Li & Willing, 2002).

Research studies show that adapting inquiry-based learning (IBL), accompanied by providing mentors, can bolster student interest in math and science learning and improve their achievements (Hulett, Williams, Twitty, & Turner, 2004; Li, 2005). This kind of approach to teaching and learning benefits *all* students and is becoming recognized as fundamental to the development of a sustainable and diversified scientific community (Schiebinger, 1997).

Related Literature

Theoretical Framework

The theoretical foundation for the design of the learning environment is a blend of IBL and *new learning technology* (with a special emphasis on videoconferencing, hereafter VC). Rooted in John Dewey's work, and aligned with constructivism, 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). IBL engages students in the *process* of learning, by encouraging them to explore and reflect upon their own questions around a concept. Students are thereby empowered in their own education; they build critical thinking skills and

develop analytical reasoning techniques, in addition to learning content knowledge. The learning is iterative and cyclical, as new knowledge brings about more questions and awareness of gaps of knowledge. Teachers are in a position of guiding and grounding students - helping to both refine their questions and to determine appropriate ways of finding answers.

The design-based research (DBR) paradigm reflects the key principles of IBL, in that it provides flexibility and responsiveness to the evolving needs of the participants, and follows an emerging, rather than prescribed, path (Anderson, 2008). In DBR, researchers and educators work collaboratively to create effective educational practices and environments, in a systematic, iterative manner of design, enactment, analysis, and redesign (Wang & Hannifin, 2005). The interventions are studied within their natural situational context and give rise to design principles, contextual theory development, tools and conceptual models (Anderson, 2005). Qualitative and quantitative data are often both collected to assess objective and subjective outcomes and meanings, and formative assessments inform the unfolding process of design. Anderson describes four stages of DBR, beginning with *informed exploration* in which the intervention is planned, followed by *enactment* (design construction), *evaluation* (context specific), and culminating in *broader impact evaluation* (multiple contexts). It is suggested the strength of DBR as an approach to advancing learning theory is the uncovering of our assumptions or conjectures about learning, through the actual process of designing interventions (Sandoval, 2004). Sandoval also suggests that it is an appropriate and appealing methodology for technology or intervention design research.

Inquiry-Based Learning and Videoconferencing

The current enthusiasm in inquiry has resulted in a flurry of research studies, each with its own definition and understanding of the term. Some studies focused on learning activities and others emphasized inquiry as a teaching technique (Barrow, 2006; Colburn, 2000). Regardless of the focus, inquiry can embrace different approaches ranging from structured inquiry, to guided inquiry, or open inquiry (Banchi & Bell, 2008). IBL has been used to teach various subjects, including mathematics, science, language arts, and health education (Kleiman, 2005; Mahony, Wozniak, Everingham, Reid, & Poulos, 2003). A growing body of research is starting to provide evidence that IBL can have a positive impact on student learning that is reflected in their academic achievements and their ability to solve problems (Geier, et al., 2008; Hmelo-Silver, Duncan, & Chinn, 2007). Many examples of successful standard-based instruction are often characterized as inquiry-based (Carter, 2004; Colburn, 2000).

Although inquiry holds promise for learning, there are concerns related to limited access to resources (Swanson, 2001). This challenge is particularly striking in rural districts and inner-city urban schools (Lee, 2002). Students in these schools have significantly lower achievement scores in math and science as compared to their suburban counterparts (Schoenfeld, 2002b; US Department of Education (USDE), 2001). Access to mathematicians and scientists is greatly reduced in these communities because teachers are not usually connected to a larger scientific network (Hanson, 1996; Hmelo-Silver, et al., 2007). Scholars in educational technology, however, claim that the use of new learning technologies can overcome this limitation (Anderson, 2008; Kubicek, 2005a). Videoconferencing, for example, allows for more extensive interaction among students, teachers and mentors in all regions and, when implemented as part of a well-designed, "multifaceted and networked learning context, it offers high levels of immediacy and social presence and therefore can play an important role" (Anderson, 2008, p.121) in student learning. Benefits to students have also included increased motivation, a greater sense of community, and improved communication and teamwork skills (Alberta Education, 2008).

In Alberta, the government has prescribed the use of a "Focus on Inquiry" model for all Albertan schools. As shown in Appendix A, the model starts at the "Planning" phase focusing on learners' interest in a topic where learners involve in determining the investigation questions and processes. Learners then move to the "Retrieving" phase where they carefully consider the information they have and want. Next step is the "Processing" phase that learners identify a "focus" for inquiry and

then “Creating” phase that they organize, internalize, and create presentations of the information. Learners then present in the “Sharing” phase and move to the “Evaluation” phase that they understand and question the assessment criteria and share their thoughts about the whole process (Alberta Learning, 2004).

Technology provides useful tools to implement inquiry strategies and mentoring that are otherwise difficult to accomplish, particularly in rural regions (Kubicek, 2005b). Using computer mediated communication (CMC), 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 & Single, 2005). Benefits of e-mentoring are categorized as informational, psychosocial, and instrumental (Single and Single, 2005).

Videoconferencing holds particular potential for educational applications (Anderson, 2008; Cavanaugh, 1999). 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 (McLellan, 1999, in Van Horn & Myrick, 2001. However, previous research (Anderson, 2008; Montgomerie, Davenport, & King, n.d) has found that the primary activity in VC sessions was lecturing, partly because teachers were often provided with some technical training, but seldom received professional development on pedagogical issues related VC.

Inquiry-Based Learning Model

We have developed a model of Inquiry-Based Learning, as shown in Appendix B, adapting the Alberta Education’s Focus on Inquiry model (2009) discussed above. In the following we describe the IBL model, substantiated by the *Biodiversity* project-one of the inquiry projects implemented in both urban and rural schools.

Before designing the inquiry projects, an overarching theme is developed that anchors all the curriculum activities for the term. Teachers developed the classroom activities based on curriculum components and mentors developed complementary VC presentations designed to encourage interaction and communication with the classroom. For example, in the urban school, the overarching questions for the term were: “How does understanding multiple perspectives shape the way we live in the world? In what ways does diversity shape our understanding?” (Curriculum Newsletter, Sept. 2005). Each project is typically structured based on the following procedure:

1. *Encounter*: teachers initiate an inquiry project through different activities ranging from reading newspaper articles to watching movies. Curricular activities in math and science are embedded in current social and cultural affairs. Students start discussions about the issues arising among themselves, with their teachers, and with mentors. They begin to form questions and important issues to explore. Here, bears in the Rocky Mountains are chosen as the focal point because it has been the hot topic that year.
2. *Observation*: students observe the e-mentor’s real scientific research through one or two VC. The mentors typically would address the whole class by discussing/demonstrating their own research/work in relation to the specific curriculum topics to be taught. Each VC session lasts about one hour. In the biodiversity project, students observed full studies of GPS in the Eastern Slopes of the Rockies as performed by professionals.
3. *Activities:* After the VC sessions, students further research the topics in-depth, reflecting on what they have learned. Working individually or collaboratively, they research and gather information, identify issues, key concepts, and ideas for further research, again interact with teachers and mentors face-to-face (F2F) or using CMC. In this study, mentors developed mapping and graphing worksheets for teachers. By mapping the

habitats of individual bears, discussions around conservation were explored. This led naturally into later VC sessions where mathematics (e.g., 2/3D shapes) was used to demonstrate how scientists might develop recommendations for preserving habitat. Students discussed issues around biodiversity with scientific understanding through extensive research; they critically analyzed the information from a number of perspectives (e.g., hunters, conservationists, farmers, and bears).

4. *Presentation*: Student-generated knowledge is then shared within the learning community. A culminating VC session allows students to be active leaders by presenting their research results, often based on the work of small groups. The mentors critique students' work and offer further insights into the curriculum topics/key concepts, connecting with the mentors' own research and the real life application.
5. *Synthesis*: After this culminating VC session, students are guided to synthesize and reflect on their learning experience, and then put their knowledge to use through different activities. Information collected also shapes the design of subsequent inquiry projects, which goes back to the "encounter" stage, thus starting a new cycle.

Research Questions

This study examines the effects of an IBL environment, with the support of VC on both rural and urban secondary students' mathematics and science learning. While the design of the research was intended to include voices from both rural and urban schools, the scope of this study does not extend to comparing the experience of these populations against each other. Specifically, the following two research questions guide this study:

- In what ways, if any, does the IBL environment with the support of VC impact student beliefs and learning outcomes? (For the purpose of this study beliefs include student perception and assumptions of the value of science and math in their everyday lives, of potential career opportunities, and of the people who work in these fields.)
- What challenges emerge in the IBL environment with secondary students in both rural and urban schools?

Methods

This design-based study used a mixed methods approach for collecting data, and focused on affective and cognitive learning outcomes. Collecting data simultaneously provided a broader perspective on the phenomena, with the qualitative data helping to describe aspects the quantitative data cannot address (Creswell, 2003). The adoption of a design-based research paradigm offered an excellent opportunity for linking theory to practice (Design-Based Research Collective, 2003). The DBR process of this study was developing, evaluating, and refining the design of an inquiry-based learning environment, such as the learning activities, and use of VC for e-mentoring. Curriculum activities were designed and developed with input from researchers, teachers, mentors, and students. These activities were then implemented and analyzed, which in turn informed the refinement and redesign of future activities. In other words, this research occurred "through continuous cycles of design, enactment, analysis and redesign" (Design-Based Research Collective, 2003, p. 5) in order to have a better 'fit' between curriculum activities and students' interests. The iterative nature is reflected in two layers: 1) each inquiry project within a school is a cycle where the information collected shapes subsequent design; 2) the implementation in an urban school and later in a rural public school.

Participants and Setting

The research was conducted in one urban school and one rural school in Western Canada. Two

Grade 9 classes (age 13-15 years) in the urban (all female) school and three Grade 8 classes (age 12-14 years) in the rural (co-ed) school were involved. Although the original plan was to have control and treatment groups for both schools, the principal of the urban school requested the participation of both Grade 9 classes. Therefore, no control group was available in this school. Additionally, in the rural school only a math teacher was involved; consequently no science class participated in the research. The participants included a total of 114 students, three mathematics and/or science teachers, and a humanities teacher.

The treatment groups included three classes: Class 1 and 2 in the urban school and Class 3 in the rural school. Class 1 consisted of 22 learners while Class 2 had 21 learners. Two teachers taught both math and science to one of the classes. Approximately 24% of the students in this group were from different ethnic backgrounds, including four newly immigrated students who spoke English as a second language (ESL). Class 3 consisted of 26 Grade 8 (female =10, male =16) students, all Caucasians with two ESL students. Control groups consisted of Classes 4 and 5 (n=45), who had the same math teacher as Class 3. Forty-five percent of the students were females and all students were Caucasian. A traditional teaching approach was used in these classrooms.

Ethic approval was received from both the University Research Ethics Board and the school boards before we conducted the study. Following the DBR principles, we held regular meetings with the teachers, mentors, and teacher educators during the term to discuss and revise the design of the learning environment. Two female scientists/mathematicians were involved as the mentors who interacted with students using computer-mediated communication (CMC), specifically VC and email.

Data and Instruments

Both quantitative and qualitative data were collected as detailed in Table 1. Quantitative data was collected from teacher-developed, student academic tests including pre-assessment tests, unit tests, and final examinations. Student qualitative data consisted of semi-structured individual and/or focus group interviews, class observations, and assignments. In each treatment class, 8-10 participants were purposefully selected to represent the full spectrum of the students in terms of their experience and academic background (e.g., low, medium and high achievers), resulting in a total of 28 students being interviewed pre-, mid-, post-project. Also, an email interview (see Appendix C) was conducted to the whole treatment group two years after the research concluded. Eighteen students responded, yielding a response rate of 43%.

Table 1: ***Methods of Student Data Collection***

Group	Class # (student #)	Teacher	Data	
			Quantitative	***Qualitative***
I -Treatment	1 & 2 (N=43) Urban School (all girls)	• Teacher 1 (math and science teaching Class 1) • Teacher 2 (math and science teaching Class 2) • Teacher 3 (humanities teaching both Class 1 & 2)	• Pre-survey • Post-survey • Pre-tests • Quizzes • Unit tests • Final exams	• Pre-interview • Mid-interview • Final interview • Email interview 2 years later • VC sessions • Written assignments
	3 (N=26)	Teacher 4 (math only)	• Pre-survey • Post-survey	• Pre-interview • Mid-interview

	Rural school (mixed gender)		• Pre-tests • Quizzes • Unit tests • Final exams	• Final interview • VC sessions • Written assignments
II- Control	4 & 5 (N=45) Rural school (mixed gender)	Teacher 4 (math only)	• Quizzes • Unit tests • Final exams	

Additional qualitative data collected included field observation notes and videotapes, semi-structured interviews of teachers, school documents (e.g., curriculum newsletter), teachers' reflective journals recording their actions (e.g., lesson plans, reflection), and recorded VC sessions. Situated in a larger study, this particular research primarily explored the student voice, although teacher data also informed and authenticated the analysis.

Analysis

Quantitative analysis included both descriptive and referential statistics. Depending on the available data, independent-sample or paired-sample t-tests were used to examine the impact on students. A paired-sample t-test of the pre- and post-survey was used to examine possible changes of student attitudes. Because teacher-developed tests were used for achievement data, rural and urban schools were analyzed separately. Paired-sample t-tests were employed to compare pre- and post-test results for treatment groups. For rural students' achievement data considering the treatment and control groups, an independent-sample t-test was used to determine possible differences between the groups. Missing data were eliminated and an alpha of .05 was used.

Four researchers analyzed the quantitative data independently at first, using codes and frames, to identify salient themes. They then compared their analysis, discussed similarities and differences, and developed mutually agreed themes. Table 2 provides sample codes for the examination of the impact of IBL with the reliability rate of 91%.

Table 2: ***Sample codes to probe the impact***

Code	Pre-data (e.g., interview/field notes)	Mid-/post-data (e.g., interview/field notes)
Career	• Students have misconceptions about what mathematicians do • Stereotyped notions about careers related to math/science.	• Math is building blocks for careers. • Awareness of importance of math and science • 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)
Images of Mathematicians/	Mathematician/ Scientists: e.g., male	• Gender: mathematician/scientists can be male or female

Scientists	with beard, wizard of math, white lab coats	• Broader view of what mathematician/ scientists do • Going beyond surface description (appearance) to personality traits
Dissonance		• Some students changed their views • Some students still see stereotyped image, but there's a dissonance that disrupts this image [e.g., quote: "the e-mentor is too cute to be a scientist"] • Some have no change in views about mathematician/scientists: but they may or may not have had stereotyped views to begin with

Following DBR principles (Design-Based Research Collective, 2003), we addressed the validity of the findings through iterative design, the establishment of a strong partnership between researchers and other participants, and the data collection over a long period of time (two years).

The reliability was controlled through different methods. First, to test reliability of the testing instruments for the quantitative data, correlations were conducted between the final marks and unit test scores. All the correlations were statistically significant at the .001 level. There were strong correlations among all scores, with the smallest correlation coefficient being .69, which demonstrated high reliability of the test instruments. Second, we employed different techniques including collecting different forms of data as well as from extreme cases, particularly looking for negative evidence (Miles & Huberman, 1994). Hence, we focused on not only the positive impact of the learning environment, but also on arising issues and areas of concern. Third, different forms of data were triangulated and analyzed independently by four reviewers. Fourth, we repeated analyses across different cycles of enactment to promote reliability.

Findings

Quantitative Results

Teacher-developed tests were used to examine the impact of this learning environment on students' academic achievements. For the urban school, pre- and post-tests were compared. For the rural school, both treatment-control and pre- post comparisons were conducted. Due to different systems used in pre- (144 points) and post-tests (110 points), the data were converted to percentage to make data compatible.

Urban School (Math & Science): Paired-sample t-tests (math: $t=3.87$, $p=.002$*; science: $t = 5.58$, $p = 0.001$*) showed significant gains in both math and science achievement tests. The mean grades for the post-tests (math 73.15, science 75.5) were higher than the pre-tests (math 61.39, science 66.7). See Table 3 for details. Considering the relatively large SDs, Wilcoxon signed ranks tests was conducted, again indicating significant gains (math: $z =4.00$, $p<.001$; science: $z=3.27$, $p=.001$). The t-test and the Wilcoxon test produced consistent results suggesting that the big SDs were not a concern.

Table 3: ***Urban school pre-test and post-test comparison***

Subject	Test	Mean (%)	SD	t	Sig.
Math	Pre-test	61.4	21.87	3.87	.002
	Post-test	73.2	11.8		
Science	Pre-test	66.7	14.30	5.58	.001
	Post-test	75.5	14.71		

Rural (Math): Due to administrative constraints, only one math teacher was involved in this study. A treatment and control method was adapted with 41 students in the control group and 26 students in the treatment group. Due to the lack of pre-test achievement data for the control group, t-tests rather than repeated measure ANOVA were used. An independent t-test was used to compare students' math final exams. The achievement for the treatment group (M= 97.35) was higher than the control group (M=85.4), a marginally significant difference, (t (65) =59.03, p=.056). Table 4 presents the details.

Table 4: ***Rural school final exam comparison between control and treatment groups***

	N	Mean (%)	SD	t	Sig.
Control	41	59.31	19.83	59.03	.056
Treatment	26	67.75	17.38		

When pre- and post-tests were considered, however, a significant gain was identified. The paired-sample t-test showed that the achievement of the students in the treatment class was significantly higher at post-test than at pre-test, t(25)=3.54, p=.002, indicating a significant gain in their math achievement. See Table 5 for details. Similarly, a Wilcoxon signed ranks test was conducted, again indicating a significant gain (z =5.7, p<.001). The consistent results from both the t-test and the Wilcoxon test therefore demonstrated that the big SDs were not a concern.

Table 5: ***Rural school treatment group pre-test and post-test comparison***

	N	Mean (%)	SD	t	Sig.
Pre-test	26	57.76	19.67	3.54	.002
Post-test	26	67.75	17.38		

Qualitative Results

Impact on Students

Cognitive gain: The impact of this learning environment on students' learning went beyond simply the pre- and post-test gains. Most importantly, it showed long-term effects on student

achievements. Among the 18 students who responded to our final email survey two years after the project concluded, 17 reported that their math and/or science marks had either improved or remained high. Only one stated that her science achievement improved, but her math score dropped.

Another long-term effect on some students was reflected in their increased interest and confidence in learning math and science. Their understanding of the subjects had reached a higher level. The following excerpts from students' responses, two years after the completion of the project, highlighted these effects:

> [After the project, o]ur impressions of math and science changed from thinking they were just ordinary subjects, to fields of study where our skills could actually be applied. We got to see the math and science skills that we were learning be put into action in the researching that [the mentor] conducted and the difference she was making for bears across Canada. All three of us finished with an average over 86% [in math and science] in grade 10. [K, N & A1]

It is worth noting that these three students (K, A1 & N) were all under-achievers when they entered Grade 9. Their math scores in the Canada Achievement Tests taken at the beginning of Grade 9 fell between the 43rd and 47th percentiles nationally.

> My math and science mark went up dramatically from [the VC project], I [sic] went up into the 90s in math and 80s in science in grade 10. [G]

> I found [the project] had a rather profound impact on me since after that I became more interested in science and last year in science 10 I achieved a mark of 91%. [A2]

With inquiry approach, students no longer were directed to follow a predefined procedure, but had to think critically and take ownership of their learning process. For example, their inquiry projects demanded that students make connections between subject areas and real life application, as opposed to simply memorizing facts. Many agreed that although the research tasks involved hard work and huge effort, the projects deepened their understanding of the content.

> I really personally enjoyed doing the tasks. … At first I was just wondering why [teachers] never explained some of the stuff in class and why we had to go home and research them. But then I realized that after we did our tasks, studying for a final test was easy… when I don't know things and go through such a hard time trying to absorb it, I found I did understand it better, and I did remember it…[S]

Math and science became more enjoyable subjects because the tasks were engaging, and because students now understood the content instead of purely memorizing it.

> I become more interested in science because I actually understand it now, it's not memorizing terms. We got to do a whole bunch of research and apply it to a bear's ecosystem. So now I understand it, it's not just memorizing words and stuff.

Two years later, when these students looked back and reflected on this experience, they could see more clearly the influences of this project on them.

> [I] finished with an final mark of 80 in science and mid-high 80's in math [in Grade 10]...I think (don't 4get THEIR[sic] BOTH IN IB[1]!!!). [The VC projects] made science soooooo fun… my attitude towards Math/Science changed since then---like **<u>seriously</u>**. [B, highlight and underscore are original]

[1] IB – International Baccalaureate program. A university entrance program that challenges academically motivated students within the international standards of excellence.

> The videoconferences really interested me, it was a brand new way of communication that I had never used before. I did very well in math and science in grade 10, finished math with a 97% on my math final exam in grade 10 ending up with a 90% average. My science mark was also good in the high 80's%. I'd honestly say these marks are due to the many activities that I was able to participate in the VC project [J].

Another theme that emerged was how students became more interested in the broadband, interactive technology. They had a better understanding of how this technology can be used in learning. Their interest in the technology itself and the new ways of learning in turn inspired their learning of the subjects.

> I remember that using this technology really had us learning in a completely different way…we were having so much fun doing something we had never tried before. [M]

Multidisciplinary approach: Interweaving math and science learning into current social affairs and the interdisciplinary approach enabled students to realize the importance of the subjects. For example, in the gemstone project, students were asked to choose particular type of gemstones and find interesting stories related to them, such as conflict diamonds in Africa.

> I like the gem project because we got to pick an interesting story to go along with our gems [H].

Some students, although they disliked this approach because of the hard work involved, admitted that the tasks resulted in deepened understanding:

> I don't really like [the inquiry projects] because I have to bring everything I understand and actually understand it and be able to explain it in the same and different subjects [C].

Students also had a broader understanding of scientific terms and concepts. This was reflected by their more frequent use of scientific terms and applying them to life outside of the classroom.

> I think about [science] more … I got home, saw my dog and I [realized], she's probably a pure bred poodle. [C]

Careers: Interacting with mentors helped students to better understand what mathematicians or scientists might do, and opened their eyes to career possibilities.

> I just think that there are so many [math- /science-related career] choices, that's what I've discovered. Even going to the teleconference, listening to [the mentor] talking about her experience in university, just shows how much there are out there. It's really huge [T].

This experience also had long lasting effects on students in their career choices. Increased interest led to heightened confidence in math and science, which ultimately resulted in broadened views and opened up more options for students. Even two years after the project was completed, students (now in Grade 11) commented on how that experience had changed them:

> The [experience] gave me a broader perspective of the different possible careers/jobs which can be done with certain understandings of sciences/mathematics. It makes university quite the exciting wait [A].

> Since the [VC project], I have had a far greater interest in Biology. When we studied the genetics especially, that caught my interest, and last year [Grade 10] in the biology unit in science, my mark went up drastically. I think this is because not only am I so interested in this topic, but I know how it can be applied. Seeing how math and science were put to work in that VC project really gave me a shove. It made me realize that all this studying isn't just

> for x number of school years, it's for careers. [C]

Decreased anxiety: Many of these students, especially in their late junior high years, reported feeling stressed because it was a critical period of time for them. The high levels of anxiety were apparent when they described their heavy academic loads and the pressure of choosing the correct career path. Learning in this inquiry environment, however, helped decrease students' anxiety. For example, a mentor shared her own journey in science where she changed fields in her university years. This created huge excitement amongst students: it was the topic of conversation on way back to school on the bus, the next day, and several days later in their Grade 10 election courses 'consultation'. This gave the students a sense of relief – one could change her mind and fall in love with another discipline at any point, and still be successful. It opened potential opportunities for the students and significantly impacted on them as they were deciding on future directions for their senior high years.

> Our school is putting all the pressure on us, you gotta get your homework done, you gotta do this… and then [the mentor] made different career choices and she changed her mind a lot, and she's really successful. Wow, so I can change my mind too [O].

Images of Mathematicians and Scientists: The pre-interview with students indicated that many held stereotypical images of what a mathematician or scientist should look like or do, although they understood that, theoretically, mathematicians and scientists could be anybody.

> My general mathematician/scientist look is big hair, little nerdy glasses, and somehow I see a lab coat, white lab coat [A].

After interacting with the mentors, the students' notions shifted and went beyond physical attributes; they focused more on important personality traits for mathematicians and scientists.

> I think scientists and mathematicians have to be really dedicated and they have to be people that never give up, they just keep on going, they're excited to keep going. [T]

For a few students, their stereotypical notions didn't completely disappear. Their experiences with the mentors, however, had created a dissonance in their prior beliefs about mathematicians and scientists. Such dissonance, we argue, might lead to a more balanced understanding about them.

> This is going to sound really stereotypical, but I think [the mentor] is too cool to be a scientist. It just sounds horrible, but she doesn't seem geeky and she doesn't like a typical scientist, she seems like she is a normal person. [O]

Most importantly, this experience had much longer and broader effects on the students and people surrounding them. Their openness and knowledge about math- and science-related careers influenced people in their new schools:

> [the experience] has opened our view of women in the world and, now in high school, [we] bring a different view to our classes today and open teachers' minds too. [A2]

Experiences with a mathematician/scientist: Some students had negative experiences with mathematicians or scientists prior to this research. For example, several students had an experience in Grade 7 with a visiting mathematician, who, instead of promoting students' interest in the subject, intimidated and even insulted students:

> She [was] dissing us, and she'd say, "You won't like this." But we're supposed to be learning this….Where she says, "You won't like it," turns us off. [A]

> She was really upset when we said that Pythagoras found out the theory for $a^2+b^2=c^2$, she was really upset about that. She said it was a scam and yelled at us five times. [M]

The experience and interaction with the mentors in this project provided a counterbalance for such negative experiences. Students started to realize that mathematicians and scientists could be cool women and positive role-models, who accomplish what they want.

> I knew that mathematicians and scientists were like normal people. But I still thought they were nerds, up until I met [the mentor]. Now that's a normal person and she's still a scientist/ mathematician. She grew up as a teenager she did all these cool things. [S]

Increased confidence: Another long term effect on students was their increased confidence through the learning experiences and interacting with the mentors. This was particularly significant for female students, especially the ones who were skeptical about their abilities to choose math-/science-related careers. From teacher observations, students' interviews and their learning outcomes, it was evident that those students gradually built up their confidence. Their heightened self-confidence in math and science led to their continued success in their subsequent years of schooling. The following students' responses two years after the project concluded demonstrated this:

> The VC project made me more confident in my abilities to be a female scientist or mathematician. My mark in these subjects stayed high (my IB math mark is 89%!). Seeing and conferencing with the [e-mentors] really helped my self confidence in these fields [S].

> I now have such confidence in myself that I believe I can do anything that I put my mind to. Seeing such successful e-mentors in not very typical careers help[ed] me to realize that [J].

Negative results

Although the IBL environment with the support of broadband interactive technology showed positive short and long-term effects on secondary students in math and science, the analysis of data also revealed a few concerns. These concerns arose from the inquiry approach and the technology integration.

Frustration with inquiry: Although many of the students enjoyed the inquiry approach which allowed them to take ownership of their learning, a few students indicated their frustration with the open-endedness of some assignments. They would appreciate more guidance directing their learning and completing assignments. For example, one student noticed that more clear instruction in the tasks with specific timelines for the projects would alleviate anxiety and enable her to stay on track with her inquiry projects.

> I think [the teacher] is trying to prepare us for university and high school when you are really independent, and this is really good….but we're still in grade 9, I think we should still be taught and we still need some guidance… I don't feel there are enough guidelines. [T]

Boringness: Students disliked a prolonged time period focusing on a single topic which led to boringness. This theme arose during the mid-point interview, which prompted us to refine the curriculum activities soon after.

> I've always like science, but this bear project got tedious … [the unit] was a really long unit and got boring [K].

Teachers and mentors were able to stay in touch with the classroom using feedback from the inquiry projects and therefore better able to mitigate a theme's tedium by making adjustments to

the topic of interest. For example, 2D and 3D shapes were started near the end of the biodiversity and bear theme but when students became increasingly disinterested, the theme was switched to gem stones. Teachers and mentors were able to maintain the mathematical geometry connections as well as inspire new interest in the lessons from the students. This also brought in new connections to science chemistry curriculum, humanities discussion topics, as well as exposure to new technologies related to geology, mining, and chemistry.

Technology: VC was new to the students and the novelty of the technology initially created excitement amongst them for using it. But we soon realized that novelty of technology could not be a long-term motivator. Rather, increasing interactions amongst students and the mentors was critical to engage students. We modified the learning activities for the subsequent VC sessions by having less lectures from the mentors and including more student-led activities with feedback from the mentors.

Although VC with broadband connections provided a useful tool to connect people, students realized that they always needed facilitators, whether a teacher or a mentor, to be present in the physical environment.

> I love pushing buttons [in VC], but if you had to have that full time, I won't be able to learn anything, absolutely nothing, I need someone there with me. [A]

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. At best, the technology glitches were just a slight annoyance, but in worse cases, they had 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.

Readiness: Students' readiness was another important factor to consider when creating opportunities for interactions. In one VC session, we encouraged students to share their biodiversity group assignments with the mentor, hoping to arouse their interests through active participation. To our surprise, students were reluctant to present their work because the teachers had not checked it yet. They commented:

> I don't think we were told that we were presenting so we weren't ready for it…I do not like being proved wrong….I don't like being proved wrong publicly even more. [K]

Most students likely have minimal presentation experience to individuals outside of their school and classroom so mentors should be sensitive to the long-term influence of a negative experience. However, the hesitancy to present incomplete work also suggests the students were mindful of the quality of their work, took ownership of it, and wanted to be proud of what they presented. Mentors should be trained to focus on positive feedback as maintaining the students' confidence is vital for future participation and learning.

Conclusions

This study extends our knowledge in three important ways. First, the successful establishment of IBL environments in both urban and rural schools demonstrates a feasible model of inquiry based learning with the support of e-mentoring. Second, few, if any, research studies have focused on the use of VC in an IBL environment. Third, the inclusion of rural regions in the study is particularly important, due to a scarcity of research on rural students. Although difficult to pinpoint specific aspects that were responsible for positive outcomes, the critical issue is that a carefully designed, theory-driven learning environment, as a whole, had a positive impact on students.

In this study, both urban and rural students showed significant gains in their math and science

grades. The achievement gains are reflected not only in their pre-test and post-test scores, but also in their reported marks even two years after the project was completed. This is consistent with previous research results that an inquiry-based approach can positively impact students' academic achievements (Amaral, Garrision, & Klentschy, 2002; Elmore, 2000; Newmann, Bryk, & Nagaoka, 2001). Given the fundamental importance of students' academic achievements for their subsequent education and occupational success, the long-term effect of this research warrants further discussion and points to the value of an IBL approach. One may question whether the pre- and post-results truly indicated that this IBL environment was responsible for students' learning gains or if it was simply short term effects caused by some random change. We argue that this pre- and post-achievement gain, coupled with students' continued success in math and science learning well into their subsequent years of study, demonstrates a strong impact of this IBL environment on learning outcomes.

Further, students showed an increased interest in math and science. Through scientific inquiries, students began to take ownership of their learning. This is reflected in their willingness to analyze significant issues, to examine the world from multiple perspectives, to take pride in their work, and to challenge what is often taken for granted. For instance, one aspect of learning biodiversity was through the GPS systems with the help of the mentors. Students saw the scope of the issues beyond what we could teach in traditional stand and delivery mode. Seeing full studies of GPS in the Rockies as performed by professionals has allowed the students to understand varied fields of science in actions. Applying their math and science research results prompted students to write recommendation letters to government officials regarding bear conservation. The responses from the government officials (e.g., the Premier and the Minister of Environment, see Appendix D) were the highlight of the project since students could see how their school learning is connected with their life and how they can contribute to public policy and shape the world they live in.

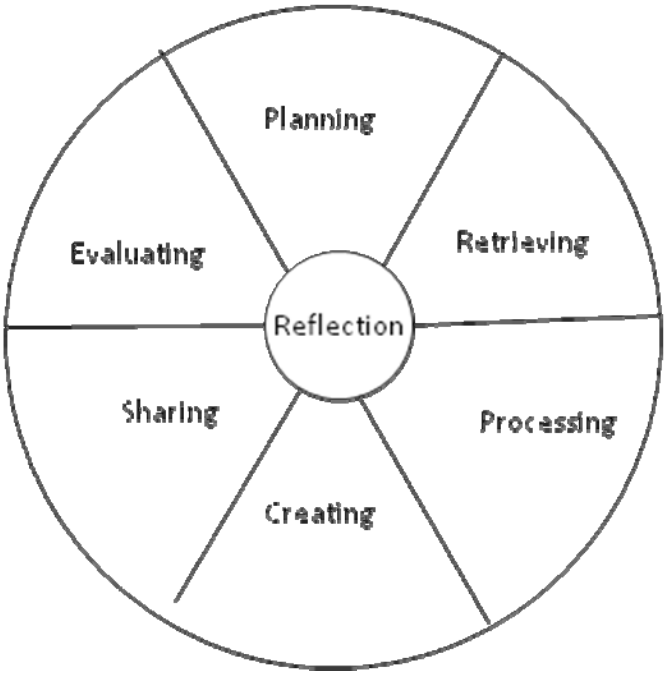
Junior high school is a critical time for students to think about career directions. Our research results show that the students' experiences, particularly with the e-mentors, were helpful for providing students with insight about the diversity of career opportunities in math and science-related fields, and generating excitement about new career directions. Although students' stereotypical notions of mathematicians and scientists were not completely dispelled, it facilitated well-rounded notions of who could be a scientist or mathematician. This was particularly important for the students with negative experiences with mathematicians or scientists in the past, since their positive interaction with the e-mentors allowed them to imagine how they could follow a similar career path. The impact of this research goes beyond the participating classrooms in a particular year. As shown in the students' responses two years after the project concluded, these students influenced peers and teachers in their new schools by bringing new ideas and diverse opinions about math and science and related careers.

In this study, we also identified some issues that pointed to better ways to design the learning environment. Student frustration with the lack of guidance suggested that designing inquiry projects should not overlook the importance of carefully guided instructions and directions, while providing flexibility to allow students' exploration based on their needs. Further, a diversity of topics needs to be considered to avoid monotony. The focus should be on the development of thoughtfully designed learning experiences based on students' interests rather than on the novelty of technology. The technical issues, especially the audio quality, should not be overlooked, because they can negatively impact learning.

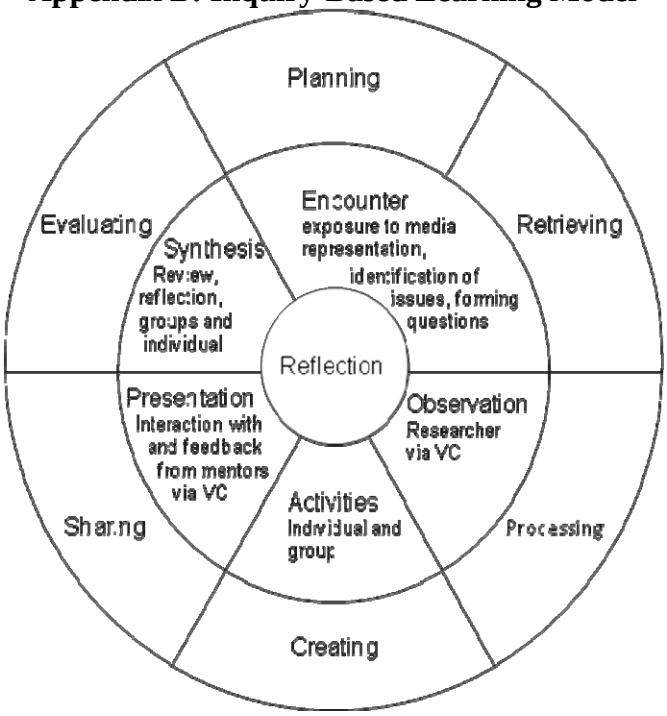
Acknowledgment:

This research was supported by a standard research grant from the Social Sciences and Humanities Research Council of Canada (SSHRC, Government of Canada) to the first author. The views and findings expressed here do not necessarily reflect the views or positions of SSHRC.

Appendix A: Focus on Inquiry Model



Appendix B: Inquiry-Based Learning Model



Appendix C: Email student interview questions two years after the project concluded

1. Based on your VC project, how did your impressions, interest and/or performance in math and science change? (You can share your Grade 10 mark if you like. How do you feel about yourself as a mathematician or scientist?)

2. What did the projects (e.g., bear project) teach you about understanding and analyzing data? How has this helped you in current school projects? How might it help you in future studies?

3. How did the video-conferencing project change, if any, your:
   a) career goals?
   b) plans for college or university?

Appendix D. Response letter from the Premier

LEGISLATIVE ASSEMBLY
ALBERTA

HONOURABLE RALPH KLEIN, MLA
Calgary-Elbow Constituency

March 23, 2006

Dear Students:

Thank you very much for your thoughtful letters regarding grizzly bear conservation in Alberta. I am always pleased to see young Albertans take an interest in matters that are important to them, and your comments are welcome.

The Alberta government recognizes there is a problem with wildlife vehicle collisions along the Trans Canada Highway and its toll on wildlife populations. Highway impacts on wildlife have usually been viewed as road mortality and threats to selected populations of animals; however, it is now viewed from a landscape ecology perspective. Highways have the potential to cause the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow in a breeding population.

One solution, as some of you point out, is to build fences, underpasses, and overpasses to try to reduce these collisions and provide travel corridors for wildlife. The fence in Banff National Park has reduced ungulate wildlife road kill by 96 per cent. Monitoring movement of animals through the crossing structures has demonstrated that both ungulates and carnivores are using them, and wildlife managers are still learning how to make overpasses and underpasses more effective.

It is expected that present overpasses will be more efficient as new vegetation grows on overpasses and the animals will no longer see the highway as they approach or travel on the overpass, and they will be less bothered by traffic noise. The program of fencing and providing movement corridors is continuing along the Bow Corridor outside of Banff National Park as funding becomes available. New structures will take into account the things learned from the original structures and should be better in providing wildlife movement corridors. For more specifics of what is happening in Banff National Park, I encourage you to contact park services by writing to them at Box 90, Banff, Alberta, T1L 1K2.

.../2

Legislative Office: 307 Legislature Building, Edmonton, AB T5K 2B7 Telephone: (780) 427-2251 Fax: (780) 427-1948
Constituency Office: #128, 9707 Elbow Drive S.W., Calgary, AB T2V 0E3 Telephone: (403) 252-0346 Fax: (403) 252-0520
calgary.elbow@assembly.ab.ca www.assembly.ab.ca

Additionally, you may be interested to know, the Alberta government recently announced that we are suspending the spring grizzly bear hunt until DNA census data has been collected throughout the province, which is expected to continue over the next few years. In addition to suspending the hunt, and as part of its precautionary approach to sustainable management, the government has renewed its commitment to a number of other proactive actions including:

- habitat mapping and continuing DNA census to establish baseline data on population estimates;
- education programs for Albertans and industries operating in bear ranges to reduce the occurrence of conflicts with bears, including bringing the BearSmart program into communities; and
- on-the-ground bear aversion, vegetation management, emergency response, access management to increase public safety, and reduce bear encounters.

These are just some of the actions government is taking in grizzly bear conservation. For additional information on grizzly bear management in Alberta, you may want to visit our website at http://www3.gov.ab.ca/srd/fw/bear_management/index.html.

Thank you again for writing. Best wishes for success in your studies.

Sincerely yours,

Ralph Klein

RK/hp

cc: Honourable David Coutts
Minister of Sustainable Resource Development

References

Alberta Learning. (2004). *Focus on inquiry: a teacher's guide to implementing inquiry-based learning*. Edmonton: Alberta Learning.

Amaral, O., Garrision, L., & Klentschy, M. (2002). Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal, 26*(2), 213-239.

Anderson, T. (2008). Is videoconferencing the killer app for K-12 distance education? *Journal of Distance Education, 22*(2), 109-123.

Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and Children, 46*(2), 26-29.

Barrow, L. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education, 17*(3), 265-278.

Carter, A. (2004). Autonomy, inquiry and mathematics reform. *The Constructivist, 15*(1), 1-15.

Cavanaugh, C. S. (1999). The effectiveness of interactive distance education technologies in K-12 learning: A meta-analysis. *International Journal of Educational Telecommunications, 7*(1), 73-88.

Colburn, A. (2000). An inquiry primer. *Science Scope, 2000*(March), 42-44.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

Elmore, R. (2000). *Building a new structure for school leadership.* The Albert Shanker Institute.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., et al. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922-939.

Gonzales, P., Guzman, J., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., et al. (2004). *Highlights from the trends in International Mathematics and Science Study (TIMSS) 2003*. Retrieved from http://nces.ed.gov/pubs2005/2005005.pdf.

Hanson, S. (1996). *Lost talent: Women in the sciences*. Philadelphia.

Hmelo-Silver, C., Duncan, R., & Chinn, C. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107.

Hulett, L., Williams, T., Twitty, L., & Turner, R. (2004, April). *Inquiry-bsed classrooms and middle school student perceptions about science and math.* Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.

Kleiman, G. M. (2005). Does technology combined with inquiry-based lessons increase students' learning? Retrieved September 19, 2006, from http://cosn.org/resources/edc/vol_1.pdf

Kubicek, J. (2005a). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology, 31*(1), 51-64.

Kubicek, J. (2005b). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology, 31*(1), 51-58.

Lee. (2002). Racial and ethnic achievement gap trends: Reversing the progress toward equity? *Educational researcher, 31*(1), 3-12.

Li, Q. (2005). Infusion technology into a mathematics methods course: Any impacts? *Educational Research, 47*(2), 217-233.

Li, Q., Moorman, L., & Dyjur, P. (2008, March). *Inquiry-Based Learning and Virtual Visitation via Broadband, Interactive Technology: A Study of Mathematics and Science Learning in Rural Schools.* Paper presented at the annual American Educational Research Association (AERA) conference, New York.

Li, Q., & Willing, L. (2002). *Tech_GIRLS: Technology-enhanced Gender Inclusive Role-model Learning System*. Grant application to National Science Foundation: University of North Dakota.

Mahony, M., Wozniak, H., Everingham, F., Reid, B., & Poulos, A. (2003). *Inquiry-based teaching and learning: What's in a name?* Paper presented at the HERDSA.

Miles, M., & Huberman, A. (1994). *An expanded sourcebook: Qualitative data analysis* (2 ed.). Thousand Oaks, CA.: Sage Publications.

Mizell, A. (1999). Creating a small, small world through videoconferencing: SAXophone. *Educational Technology Research and Development, 47*(4), 102-107.

Montgomerie, T. C., Davenport, M., & King, C. (n.d). Providing quality and equitable distance education. Retrieved Sept. 22, 2008, from http://209.85.173.104/search?q=cache:HsJ-3P12kwoJ:www.racol.ualberta.ca/documents/documents/Montgomerie_PTCfinal.doc+%22Providing+quality+and+equitable+distance+education%22&hl=en&ct=clnk&cd=2&gl=ca

Mullis, I., Martin, M., Gonzalez, E., & Chrostowski, S. (2003). *TIMSS 2003 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. MA: Chestnut Hill: TIMSS & PIRLS International Study Center.

Mullis, I., Martin, M., Gonzalez, E., Gregory, K., Garden, R., O'Connor, K., et al. (2000). *TIMSS 1999: International Mathematics Report*. Chestnut Hill, MA: Boston College.

National Science Foundation. (2005). *Inquiry: Thoughts, views, and strategies for the k-5 classroom*. Arlington, VA: National Science Foundation.

Newmann, F., Bryk, A., & Nagaoka, J. (2001). *Authentic intellectual work and standardized tests: Conflict or coexistence?* Chicago: Consortium on Chicago School Research.

Sandoval, W. A. (2004). Developing Learning Theory by Refining Conjectures Embodied in Educational Design. *Educational Psychologist, 39*(4), 213 - 223.

Schiebinger, L. (1997). Creating sustainable science. *Osiris, 12*, 201-216.

Schoenfeld, A. (2002a). Making mathematics work for all children: Issues of standards, testing and equity. *Educational Researcher, 31*(1), 13-25.

Schoenfeld, A. (2002b). Making mathematics work for all children: Issues of Standards, testing and equity. *Educational Researcher, 31*(1), 13-25.

Single, P. B., & Single, R. M. (2005). E-mentoring for social equity: Review of research to inform program development. *Mentoring and Tutoring, 13*(2), 301-320.

Swanson, L. E. (2001). Rural opportunities: Minimalist policy and community-based experimentation. *Policy Study Journal 29*, 96-107.

US Department of Education (USDE). (2001). *The longitudinal evaluation of school change and performance (LESCP) in title I schools: V1: Executive summary* (No. 2001-20). Washington, DC: USDE.

Van Horn, S. M., & Myrick, R. D. (2001). Computer technology and the 21st century school counselor. *Professional School Counseling, 5*(2), 124-130.

Wang, F., & Hannifin, M. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research & Development, 53*(4), 5-23.