Blended Learning For Professional Development: An Evaluation Of A Program For Middle School Mathematics And Science Teachers

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Background: *Improving the subject matter knowledge and pedagogical skills of teachers of mathematics and science is a key priority for many jurisdictions. Blended learning is a promising, yet so far seldom used model for supporting teacher professional development. This model combines the advantages of traditional face-to-face interaction with the flexibility of online learning.*

Purpose: *In this study, we examine two one-year professional development programs for middle-school mathematics and science/technology teachers that employed blended learning. The goal of our research was to understand how the program affected teacher attitudes toward and pedagogical practices in these subjects and on student perceptions and learning of the subjects.*

Participants: *Participants in the study were 68 mathematics and 65 science/technology teachers in grades 6, 7, and 8 in several school districts in a large urban center, along with their students: 477 students from the mathematics teachers' classes and 551 from the science/technology teachers' classes.*

Program: *The blended learning program, known as the Teacher eLearning Project (TeL), began at the start of the school year with a module that consisted of a daylong face-to-face session followed by an eight-week online session. The first year of TeL focused on the mathematics teachers who had a total of three modules to complete; in the second year, science/technology teachers had two modules.*

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Research design: *We used Guskey's (2000) five-level evaluation framework to assess the impact of the programs on teachers' attitudes and knowledge, institutional support for the programs, changes in classroom practices, and student perceptions and learning of the subjects. Data were obtained using a pre-post design that included surveys, classroom observations, and key informant interviews.*
Findings: *Overall our results indicate that the program appeared to influence positively teacher attitudes and content knowledge in certain curricular areas and motivated many to transform their classroom practice to varying degrees. Despite this, student responses were mixed: students viewed mathematics less favorably by the end of the program, but became more positively inclined towards science/technology.*
Conclusions: *The blended learning model shows potential for teacher professional development, although further research preferably through controlled studies is needed. Aspects that need to be examined further include the nature of the online tasks given to teachers, the role of the online facilitators, the impact on student achievement, and the implications of providing teachers with less release time than was available in this study.*

Improving the subject matter knowledge and pedagogical skills of teachers of mathematics and science, particularly in middle schools, is a key priority of most district, state/provincial, and federal education authorities (OECD, 2005; Ontario Ministry of Education, 2004; U.S. Department of Education, 2005). Although there is general consensus on the elements of what constitutes effective teacher professional development for mathematics and science teachers, the challenge is how to design and implement a program that embodies these principles (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). One approach that appears promising, now that the Internet is widely accessible to teachers, is to design programs that combine traditional face-to-face professional development sessions with self-directed online learning. Ideally this model, known as blended learning, allows developers to build programs that can combine the increased motivation, socialization, intense focus, and spontaneity that can occur in live sessions with the online sharing of thoughts and reflections, extended discussion, and learning at times and locations convenient to the learner (Bonk & Graham, 2006). In this article, we report on the evaluation of the Teacher eLearning (TeL) Project, a two-year professional development program for middle school mathematics and science teachers that employed a blended learning model. The focus of our research was on how the program affected teacher attitudes toward and pedagogical practices in these subjects and on student perceptions and learning of the subjects.

PROFESSIONAL DEVELOPMENT AND BLENDED LEARNING

In the last decade or so, a consensus has emerged that traditional strategies of professional development, based on one-shot workshops and lectures from outside authorities, offer very limited growth opportunities for teachers. Research has shown that professional development is most effective when it is long term, collaborative, school based, focused on the learning of all students, and linked to the curricula that teachers have to teach (Hiebert, Gallimore, & Stigler, 2002). When professional development is conducted in this way, teachers of mathematics and science are more likely to change their instructional practices, gain greater subject matter knowledge, and improve their teaching skills (Garet, Porter, Desimone, Birman, & Yoon, 2001). The potential for the professional development to have a direct positive impact on student achievement is also increased (Cohen & Hill, 2001; Darling-Hammond & Youngs, 2002; Wenglinsky, 2000). Moreover, Loucks-Horsley et al. (2003) emphasize that current conceptions of professional development that focus on teacher collaboration and experiential learning mirror contemporary reforms of mathematics and science education. They contend that teachers who participate in professional development activities of this nature are better prepared to introduce best practices into their classrooms as they have experienced this kind of learning themselves.

Many different professional development strategies have been employed to incorporate at least some of these principles. The choice of strategy depends upon the particular purpose of the professional development—whether it is to develop awareness to new approaches or content, build content and pedagogical knowledge, translate new knowledge into practice, practice teaching in new ways, or to reflect on teaching and learning (Brown & Smith, 1997). Strategies that have been used for mathematics and science include professional networks, study groups, intensive summer institutes, partnerships with scientists or mathematicians, coaching, lesson study, examining student work, and linking professional development closely to new curriculum materials (Loucks-Horsley et al., 2003). One new professional development strategy starting to gain popularity is blended learning.

As blended learning is a relatively new concept, there are many interpretations of the meaning of the term (see Graham, Allen, & Ure, 2005; Oliver & Trigwell, 2005; Whitelock & Jelfs, 2003). At issue is exactly what components or experiences are blended: traditional face-to-face instruction with web-based instruction; different tools within an e-learning environment; pedagogical approaches, irrespective of learning technology use; or different kinds of student learning experiences. The consensus (and the definition used in this study) is that blended learning environments combine some face-to-face instruction where learners are colocated, with web-based instruction where they are not at the same location. This combination of face-to-face and online learning can result in a transformative learning experience, argue Garrison and Kanuka (2004), because course participants can benefit from being connected to a learning community regardless of whether they are physically apart and together. They add that when the dynamic of fast-paced, spontaneous verbal communication characteristic of face-to-face learning is combined with the potential for thoughtful discussion and reflection online, the educational possibilities are multiplied.

Blended learning should not be seen as an add-on to regular classroom instruction, nor as an effort to find simply the right mix of technologies (Garrison & Kanuka, 2004; Richards, 2003). Instead blended learning requires "rethinking and redesigning the teaching and learning relationship" (Garrison & Kanuka, 2004: p. 99). Several guidelines for the (re)design of blended learning courses have been suggested. In higher education, where blended learning is becoming increasingly prevalent, Ausburn (2004) and Danchak & Huguet (2004) argue in unrelated studies that blended learning courses must be designed around principles of adult learning that favor multiple learning activities from which the learner can choose, personalization rather than a one-size-fits-all design, a variety of learning pathways and resources, and a community with whom participants can interact including the instructor. At a more concrete level, Twigg (2003) describes how technology can be blended into traditional undergraduate courses; and Owston, Garrison, and Cook (2006) illustrate how faculty in eight Canadian universities structured their courses to take advantage of the potential of blended learning.

Most outcomes research on blended learning has been done at the undergraduate level, where it tends to show that blended learning has some distinct advantages for students over traditional lectures and fully online courses. Twigg (2003) reported that student learning improved in 20 of the 30 courses she studied compared to the former versions of the courses, while the rest showed no significant difference. The University of Central Florida's extensive experience with blended learning suggests that on average, blended courses have higher success rates and lower withdrawal rates than their comparable face-to-face courses and fully online courses (Dziuban, Hartman, Juge, Moskal, & Sorg, 2006), a finding also supported by Twigg (2003). Additionally, the majority of faculty teaching in those courses at the University of Central Florida indicated that more and higher quality interaction occurred in their blended courses than in their comparable face-to-face sections. Owston, Garrison, and Cook's (2006) study reported that students liked the fact that blended learning provides scheduling flexibility and varied learning opportunities, while maintaining traditional classroom experiences such as in-class discussion. Both faculty and students in the study felt that the online component of blended learning encouraged the development of critical thinking skills, and faculty found that they got to know their students better as individuals in blended courses than they would have in traditional lectures. Additionally, Owston et al. (2006) and Twigg (2003) found high levels of student satisfaction with their blended course experiences.

Blended learning for teacher professional development is just beginning to be studied. Curtis and Swenson (2003) found that the blended format provided an effective model for meeting the needs and learning styles of busy teaching professionals because it allows for a more flexible study schedule than a lectures-only course, and Motteram (2006) discussed how he used it to provide language teachers in a graduate program with relevant skills and the opportunity to reflect online about their practice. Similarly, Oliver, Herrington, and Reeves (2006) described and illustrated how a blended learning environment in a graduate education course can be designed around authentic learning experiences to bring meaning and purpose to the learners' activities. Two teacher professional development projects, Capital Area Technology and Inquiry in Education (CATIE) (Holmes, Polhemus, & Jennings, 2005) and Teacher Institute for Curriculum Knowledge about the Integration of Technology (TICKIT) (Bonk, Erhman, Hixon, & Yamagata-Lynch, 2002), demonstrated how online activities and resources can be blended with in-school experiences to create programs that would not be feasible to offer entirely on-site. Blended learning offers other advantages that may be relevant to professional development. These include: allowing instructors the opportunity to develop e-learning skills in small increments; making training materials available to learners before or after face-to-face workshops; and preserving the investment in traditional teaching materials that have worked well in the past (Driscoll, 2002). Our study of the TeL Project sought to extend current research, which has focused primarily on how blended learning has been implemented and the practical advantages of the model, and examine how professional development offered by blended learning can impact teacher classroom practices and student learning as a consequence.

THE CURRENT STUDY: THE TEL PROJECT

The TeL Project was offered by a non-profit agency devoted to advancing public education in Canada. The idea for the project arose from a senior level advisory committee of the agency which recommended that action be taken to enhance the skills of urban grade 6, 7, and 8 teachers of mathematics and science/technology. With financial support from several public and corporate funding agencies, a two-year professional development project was developed and implemented by agency staff. The first year of the project was devoted to professional development of mathematics teachers, the second year to science/technology teachers. The authors were contracted through their university to be arms' length evaluators of TeL.

TeL had two main goals with regard to mathematics and science/technology education: (1) to improve teacher attitudes, knowledge, and classroom practice; and (2) to improve student attitudes toward, engagement in, and learning of the subjects. The theory of action articulated by the developers was that a blended learning model would allow the program to achieve these goals by operating over an extended period of time so that teachers could develop their skills within the confines of the program; they could remain in their classrooms for the most part and thus reducing the number of costly face-to-face sessions; and receive ongoing feedback online from their peers and expert program facilitators as they experimented with new pedagogical approaches in their classrooms.

During the first year of TeL, the developers employed an implementation model that began at the start of the school year with a daylong face-to-face session followed by an eight-week online session. This pattern was repeated two more times with the addition of a final face-to-face session. Thus teachers had four face-to-face sessions and three eight-week online sessions. Each pairing of a face-to-face session and subsequent online session was referred to as a module, and each module had a specific theme. Schools that had teachers participating in TeL were provided with a budget to hire substitutes for teachers attending the face-to-face sessions; they were also given funds to release teachers from their classrooms for a half-day per week during the eight-week online periods to provide them with time to plan and participate in online activities. The model proved somewhat problematic in the first year because the second module conflicted with normally busy times for teachers in late November and December when they had to deal with the preparation of report cards, parent-teacher conferences, and winter holiday events in their schools. As a result, teachers did not participate online as fully as they might otherwise have. Therefore, during the second year, only two modules were offered for the science/technology program with a hiatus during late November and all of December.

All of the modules in TeL related directly to the Ontario (Canada) provincial curriculum that the grade 6, 7, and 8 teachers in the project were responsible for teaching (Ontario Ministry of Education, 2007). The TeL mathematics program, which focused on strands in Number Sense, Geometry, Algebra, and Probability, was designed to help teachers develop a "balanced approach" to mathematics instruction (Kilpatrick, Swafford, & Findell, 2001). This approach aims to provide students with rich problem-solving contexts that allow them to develop their understanding of mathematics and give them ample opportunity to practice and consolidate their skills. A typical lesson that uses this approach consists of three parts: (1) a beginning, where the teacher poses a problem that offers a range of entry points for students at different levels and sets up an investigation; (2) a middle, where students work in small groups to make sense of the problem while the teacher circulates among groups and asks careful questions that will help students to deepen and clarify their thinking; and (3) an end, where the teacher asks students to share, explain, and examine a range of solutions with the whole class, discussing the common elements, looking for patterns, and making sense. The science/technology program dealt with stands on Life Systems, Earth and Space Systems, Matter and Materials, and Energy and Control.[1] The program emphasized that teachers should provide as many hands-on activities as possible for students, typically through group work. These activities should allow students to discover and learn fundamental concepts through investigation, exploration, observation, and experimentation, and to place these concepts in the social, environmental, and economic contexts in which their relevance and application will be most evident.

The face-to-face sessions, which were led by curriculum consultants from participating school districts, typically began with a whole group introduction to the upcoming module topic in the morning. Frequently, leaders would ask the group to break up into small working groups to try out an activity or discuss a topic. During the afternoons, teachers broke into one of four or five multi-school teams that paralleled the online discussion group in which they participated. This gave teachers an opportunity to work on hands-on activities, share their experiences in trying out ideas in their classrooms, and discuss the topics presented during the morning. At the final session in each year, small teams of teachers presented projects they developed to the whole group: the mathematics teachers presented projects on games to teach probability in their classrooms; and science/technology teacher teams presented overly complex Rube Goldberg-like machines that they had built.

The course management system eCollege was used for delivery of the online component. Each week had a theme and structured activities. In any given week, participants might do any combination of the following: download professional articles, video teaching examples, small interactive programs (applets), worksheets, and forms; join live moderated chat sessions; discuss in online forums their implementation of program activities in their classes; post reflective journals about their experiences trying out TeL Project activities; or upload their work. Each of the online discussion groups, which consisted of 10 to 15 teachers, was led by an expert teacher hired to facilitate the discussions. Additionally, the facilitators provided individual feedback on teachers' reflective journals or raised questions or discussion topics with their whole group. During the first year of the project, facilitators were not specifically trained on how to lead online discussions. As a result, they varied considerably in the quantity and quality of feedback provided to participants. To rectify the situation in the second year, the program developers held an initial face-to-face training session and conducted monthly telephone meetings with facilitators to improve their facilitation skills and develop a consistent approach in providing feedback to participants.

Design of study

As mentioned above, the goals of the TeL Project were to advance teacher practice and improve student attitudes and learning. We operationalized these goals by employing Guskey's (2000) five-level framework for the evaluation of professional development programs. Guskey argues that all too frequently evaluations of professional development programs focus only on teacher reactions to programs, while neglecting teacher learning, contextual information, and, most importantly, impact on students. To address this concern, he developed a hierarchical framework that guides evaluators to assess: (1) teacher reactions to the professional development program; (2) what teachers learned from the program; (3) changes to the school support structures that will help teachers apply the new knowledge and skills in the classroom; (4) how teachers actually apply their new knowledge and skills in their teaching; and (5) the impact of teaching with their new knowledge and skills on student learning. We hypothesized that the TeL Project would produce positive changes in each of these five factors in Guskey's model.

To assess changes in teacher perceptions (Guskey Level 1) and learning (Level 2) a questionnaire was developed for mathematics teachers and a similar one for science/technology teachers, and each was administered at both the beginning and end of the respective programs. Some questionnaire items were adapted from an instrument developed by Kennedy, Ball, and McDiarmid (1993) to assess how teachers' knowledge, beliefs, and reasoning about teaching change over time as a result of participation in various pre-service and in-service education programs. From the teacher survey portion of the Repeat of the Third International Mathematics and Science Study (TIMSS Study Center, 1998), we added questions dealing with professional development practices, specifics of the teacher's class, use of technology, homework, and assessment practices. Several questions that dealt with specifics of the teacher's class were added from the U.S. National Science Foundation-supported survey Teaching, Learning, and Computing carried out by Becker and Anderson (1998). The final versions of the surveys had 30 and 23 questions respectively for mathematics and science/technology. Most survey items asked respondents to rate the extent to which they agreed/disagreed with statements or how often they engaged in specific activities; the remaining questions required respondents to select from four or five pre-determined options. Examples of questions from the final surveys are: "Teachers should avoid calling on students who may not know the answer;" "When working with students from low socio-economic backgrounds, teachers should rely primarily on teacher-directed focused, whole-group instruction;" "If students are having difficulty in science and technology, a good approach is to give them more practice in the skills they lack;" and "If a student is confused in math, the teacher should go over the material again more slowly."

To assess Guskey's Level 3—organizational support and change—school principals were interviewed via telephone at the end of each year using semi-structured protocols. Sample questions were: "Describe any changes you have seen in the way teachers conduct their science and technology (mathematics) classes? Are teachers doing more hands-on activities, inquiry learning, or project-based work? Are teachers collaborating more often?" and "How would you characterize students' attitudes towards science and technology (mathematics) in your school in grades 6, 7 and 8? Have you noticed any changes in student attitude or motivation toward learning science and technology since your teacher(s) began the program?" For all questions, principals were encouraged to support their answers by providing concrete examples of changes they noticed.

Teachers' use of new knowledge and skills (Level 4) was assessed through (a) classroom observations at the beginning and end of each program, (b) an analysis of online discussion postings and reflective journals each year, and (c) an evaluation forum which consisted of small group interviews of teachers conducted during the last face-to-face session of each year. Observations of lessons were carried out using the following protocol: we interviewed teachers in advance of their lesson on what they were intending to teach, observed what and how they taught, and then interviewed them afterwards for their perceptions on how well the lesson had proceeded. Changes in student perceptions of learning mathematics and science/technology were assessed by comparing pre- and post-program questionnaire responses. The questionnaires were based on those used in the Science Work Experience Programs for Teachers (SWEPT) project (see http://www.sweptstudy.org/) with some additional items included from the student survey portion of the Repeat of the Third International Mathematics and Science Study (TIMSS, 1999). The student mathematics and science/technology questionnaires had 20 and 13 questions, respectively. Like the teacher questionnaires, most student questions had additional sub-questions and they were mainly Likert type with the rest requiring respondents to select from four or five pre-determined options. Typical student questions were: “I think it’s important to do well in mathematics (science and technology);” “When we begin a new topic in mathematics (science and technology), we begin by having the teacher explain the rules and definitions;” and “We work often in pairs or groups.”

The above mapping of data sources to Guskey’s levels indicates the primary data source used for a particular level. For each level at least one additional data source was used to triangulate the findings. For example, not only did we consider student survey results to assess program impact on students, we also interviewed teachers about changes that they saw in students.

All teachers participating in TeL were from schools in a large Canadian urban area and who were nominated by their principals to take part in the project because of their desire and interest to improve mathematics or science/technology instruction. Approximately half of the teachers in both cohorts were from high-SES schools and half were from low-SES schools as designated by their school districts. Sixty-eight grade 6, 7, and 8 teachers enrolled in the mathematics program and 65 in the science/technology program. Developers hoped that most of the teachers from the first year would participate in the second year, however only a small number did. Mathematics teachers had a weaker academic preparation in their subject than science/technology teachers. Forty-two percent of mathematics teachers did not have any mathematics training beyond high school and none had graduate training; the remaining 58% had at least several undergraduate mathematics courses. On the other hand, only 18% of the science/technology teachers did not have any science/technology training beyond high school, 64% had at least several undergraduate science courses, and 18% had graduate-level science training.

Approximately 10% of the participants dropped out of both programs before they ended. We obtained complete sets of pre-post survey responses from 48 teachers in the mathematics program and from 33 teachers in the science/technology program. The poorer response rate in science/technology was due to many absences from the last face-to-face session when the post program survey was administered; attempts to have teachers complete the survey later were only moderately successful. Fourteen mathematics teachers and 13 science/technology teachers were selected for observation to represent all three grades from both high- and low-SES schools. We had complete pre-post sets of survey responses from 477 students from the mathematics teachers' classes and 551 from the science/technology teachers' classes.

Data analysis

Survey data for teachers and for students for each year were analyzed separately using a repeated measures (pre-post) ANOVA design. For the student analysis only, SES was used as an independent variable. SES was not used as an independent variable in the analysis of teacher data. There was no theoretical rationale for doing this as almost all teachers received their initial training from one of several Ontario schools of education having equivalent high standards; additionally, the sample size was small for this kind of analysis. While this basic design of this study has inherent limitations (Campbell, Stanley, & Gage, 1966), we had no evidence of other significant events occurring at schools either year that would have influenced teacher practices or student attitudes significantly.

All interviews were recorded and transcribed. The project evaluation questions provided initial categories for the analysis of the qualitative data, which included interview transcripts, field notes, and online postings. From the initial categories, subcategories were derived inductively using the constant comparative method described by Bogdan and Biklen (1998).

Next, we present the results of the study under two general headings: (1) impact on teachers, where we address the first four levels of Guskey's (2000) framework, and (2) impact on students, which deals with Guskey's fifth level.

RESULTS-IMPACT ON TEACHERS

The first four levels of Guskey's (2000) framework call for assessing program impact on teacher satisfaction, teacher learning, organizational support and change, and changes in classroom practice. The impact of the TeL Project on teachers at each of these levels is addressed below.

Satisfaction with overall program (Guskey Level 1).

Overall, teachers were very satisfied with both the mathematics and science/technology TeL programs for the professional learning opportunity that they afforded. For both programs, slightly more than half of the teachers surveyed said that the program "fully met their expectations" and slightly fewer than half said that it "met their expectations to some extent." Noteworthy was the fact that none felt that the programs "did not meet many" or "any of their expectations." Our qualitative data indicate that mathematics teachers became more willing to experiment with new ideas, activities, and approaches in their classrooms as a result of the program. Even those who were already quite confident about their mathematics teaching abilities at the beginning of the program appeared to have benefited by trying new ways of having students solve problems and by thinking more broadly about the teaching of mathematics. Science/technology teachers gained confidence to experiment with different teaching approaches that featured hands-on exploratory learning, higher level questioning, use of new kinds of teaching materials, greater student autonomy for designing projects, and grouping students in mixed ability teams. Experienced science/technology teachers found the material in the course to be a helpful refresher for techniques previously learned but not necessarily implemented, and less experienced teachers valued the subject matter knowledge learned and the insights and ideas gained for effective teaching of science and technology.

Satisfaction with blended learning experience. As described above, the program consisted of a combination of face-to-face sessions and an online component. There was a general feeling that the face-to-face component, with its opportunities for in-depth sharing and exchange of ideas, was extremely valuable, and some teachers wanted more of this. Teachers in both programs felt that the sessions provided both a chance to connect with other teachers at the same grade level and share ideas, and also a chance to grow from the expertise of the facilitators and fellow teachers. Participants especially valued the opportunities to come together and celebrate their best practices, experiences, challenges, and lesson/unit plans. Teachers who were the only teacher of a particular grade level at a school also spoke of how this aspect of the program helped eliminate feelings of isolation.

With respect to the online sessions, two expectations for teachers were set out by the TeL Project developers: (1) to post their reactions to articles and other assignments each week, and (2) to post at least one reflective journal every two weeks. There were mixed reactions to these assignments from both the mathematics and science/technology teachers, with some enjoying it and participating regularly, and others participating erratically or dropping out entirely from the online component. The best indicator of commitment to online participation was the regular posting of journals as this activity required time and thoughtful reflection. In both mathematics and science/technology, journal submission tapered off as the course progressed. For mathematics, 89% of the teachers posted two or more journals in Module A, 59% in Module B, and 56% in Module C. The science/technology program had only two modules: 76% of teachers posted two or more journals in Module A and 57% in Module B. This represents a relatively weak participation rate, especially when one considers that teachers were provided with one half-day per week release time to work on this and other program activities. However, as Motteram (2006) argues, even though teachers may not participate regularly in online discussions, one cannot conclude that no teacher activity or learning is taking place as they still may being doing what they have been asked to do except not posting in discussion groups. Evidence suggests that teachers were more likely to participate if they received good quality feedback from their facilitators. When teachers commented during the evaluation forum about the quality of their online experience, they felt there was a lack of community and communication in their online sections. While they knew each other's faces, they did not even know all the names of other teachers in their online section. A common comment voiced by teachers was that "it is difficult to share with strangers."

Teacher learning (Guskey Level 2).

Teachers were asked to report on the pre- and post-surveys how well they were prepared to teach various aspects of the curriculum. Mathematics teachers (N=48) were asked about preparedness to teach eleven different areas of the curriculum. While increases in preparedness were noted for all areas between pre- and post-test ratings, statistically significant gains were noted only for the topic of Probability (p=.005). Science/technology teachers (N=33) were asked about preparedness to teach the four main strands in the curriculum. Significant increases were reported for

Life Systems (p=.010), Earth and Space Systems (p=.010), Matter and Materials (p=.005), with Energy and Control showing a non-significant increase.

Organizational support and change (Guskey Level 3)

Teachers we interviewed stated that they were provided with strong support for participation in the project through encouragement from their principals, school goals that emphasized the improvement of mathematics and science/technology teaching, and the provision of necessary resources from schools, districts, and the TeL Project itself. Principals reported that they were pleased with their teachers' participation in the TeL Project, and, in a few cases, they said that the project exceeded their expectations. Only one issue stood out as problematic—teacher release time. Even though teachers were provided with one half-day release time per week to work on program-related activities, approximately half of them did not use all the time they were afforded. Several reasons were given for this: schools could not find qualified substitute teachers; teachers felt that it was more trouble that it was worth preparing lessons for substitute teachers; teachers felt that their students were suffering academically; and, in several cases, teachers said that student behavioral problems developed due to their frequent absences from class. Some teachers also experienced resentment from colleagues who wondered why they were given so much time for professional development when they themselves had to take courses and attend workshops after school. There were several cases during the first year of the program where schools received angry calls from parents about frequent teacher absences. This did not happen during the second year because, we were told, principals did a better job of informing parents in advance that their child's teacher would be absent regularly for professional development purposes. (One principal in a high-SES neighborhood withdrew her teachers after the mathematics orientation day when she found out her teachers would be out of class so often because she felt that parents would not tolerate the repeated absences.) A final problem was that some principals wanted teachers to take one release day every two weeks rather than a half day weekly because of difficulty in getting a substitute teacher for half a day. As a result, those teachers did not participate regularly each week. The problem was exacerbated when some teachers were not permitted by their principals to remain home that day to work on the project (for reasons of public perception). While working at school, they were frequently interrupted by other teachers and job-related demands.

The most notable change in school practices resulting from teachers participating in the mathematics and science/technology programs was in the amount and nature of teacher collaboration. Examples of this cited by principals include: more reflection and sharing of ideas and practices among colleagues; teachers doing workshops at the school and district levels for other teachers; teachers presenting mathematics and science/technology teaching ideas at staff meetings; an increased number of same-grade and cross-grade team meetings that focused on pedagogical issues; and an increased number of "bring and brag sharing of lessons" and teacher "lunch and learn" sessions. Additionally, principals reported that teachers who were in the science/technology program became more involved in co-curricular activities such as the organization of science fairs and robotics challenges with other schools.

Changes in classroom practices (Guskey Level 4)

On the teacher survey, several statistically significant changes in pedagogical beliefs and practices were found between the beginning and end of each program. One question that stood out as highly significant on both the mathematics and science/technology surveys dealt with whether students should be allowed to leave a lesson "feeling confused or stuck" ($p=.000$). The results suggest that teachers believed that it was more acceptable to leave students feeling this way by the end of the program for both subjects. This suggests that teachers adopted the TeL Project's philosophy of teaching mathematics and science/technology in a more open-ended, constructivist way where students were not given solutions, but had to puzzle over them and find their own answers.

Two other questions that showed statistically significant differences between pre- and post-program surveys for mathematics teachers are reported in Table 1. Questions 18c and 27f together suggest important changes in teacher practice as teachers at the end of the program seemed more skilled in questioning and had students work in groups more often.

Table 1. Pre-Post Changes in Mathematics Teacher Practice (N=48)

	Question	Survey Mean		p
		Pre	Post	
18c	A student in your class identifies a square as a rectangle. What would you say or do? I'd ask the student, "What's a square, what's a rectangle, and try to get students to remember the difference." (Definitely do=1 to Definitely not do=4)	1.63	2.02	.012
27f	How often do you have students work in small groups to come up with a joint solution or approach to a problem or task. (Never=1 to Almost everyday=5)	3.65	3.85	.011

These changes were also consistent with the TeL Project's pedagogical philosophy.

A greater number of pre-post statistically significant changes in teachers' knowledge about pedagogy were found for science/technology teachers than for mathematics teachers. These are presented in Table 2. Results suggest teachers at the end of the program gave less emphasis to rote learning of rules (4f); placed more value on mixed-ability student grouping (11g); assigned more open-ended problems to students (6c); and used computers more often (6d). Teachers also appeared to be allowing students to work more independently as they were using more group work (7e), spending less time demonstrating experiments (8h)

Table 2. Pre-Post Changes in Science/Technology Teacher Practice (N= 33)

	Question	Survey Means		p
		Pre	Post	
4f	Focusing on rules is a good idea. It gives students a useful structure around which to learn. (Strongly agree=1 to Strongly disagree=5)	2.44	2.72	.027
11g	It is not a good idea for students to work in mixed ability small groups because the brighter students will do all the work. (Strongly agree=1 to Strongly disagree=5)	4.34	3.91	.046
6c	How often do you ask students to work on problems for which there is no immediate and obvious method or solution? (Never/almost never=1 to Every lesson=4)	2.00	2.36	.003
6d	How often do you usually ask students to use computers to solve exercises or problems? (Never/almost never=1 to Every lesson=4)	1.48	1.73	.009
7e	How often do students work in small groups without assistance from the teacher? (Never/almost never=1 to Every lesson=4)	1.97	2.30	.009
8a	How often do you spend time on students conducting experiments of their own design? (Very often=1 to Almost never=4)	3.00	2.67	.019
8c	How often do you spend time on making lecture-style presentations? (Very often=1 to Almost never=4)	2.52	2.88	.005
8h	How often do you spend time on demonstrations of experiments? (Very often=1 to Almost never=4)	2.30	2.61	.016
9h	How often are your students engaged in finding one or more uses of content covered? (Never/almost never=1 to Every lesson=4)	1.91	2.36	.007
14g	Shortage of equipment for use in demonstrations and other activities limits how I teach science and technology. (A great deal=1 to Not at all=5)	1.73	1.97	.044
18	Percentage of time teaching with textbook. (0-25%=1 to 76-100%=4)	2.39	1.94	.002

and more time having students design their own experiments (8a), and giving fewer lecture style presentations (8c). They also appeared to be relying on the textbook less (18) and finding more uses for content covered in class (9h). By the end of the program, the fact that teachers found their teaching less hampered by the shortage of equipment would suggest that as the program evolved, teachers found ways to do science and technology experiments using everyday materials, mitigating the problem (14g).

In general, the views of school principals supported teacher responses. For both subjects, principals noted that teachers showed increased confidence in using a variety of instructional strategies and materials because of the project. Mathematics teachers made more use of manipulatives (e.g., three-dimensional paper models of geometric shapes), and science/technology teachers increased their use of school lab facilities and equipment for hands-on activity. Both groups of teachers reportedly made greater use of computers and the Internet for classroom activities and projects. Additionally, principals said that teachers began to play a leadership role in their subject areas: colleagues saw them as “experts” who could be called upon for help in curriculum and teaching matters.

Classroom observations of the progress made by the sample of teachers we observed were less sanguine. Presented below are examples of “weaker or little changed lessons” and of “stronger lessons” for mathematics and science/technology. Of the 14 mathematics observations, half of the lessons were judged stronger; eight (61%) of the 13 science/technology lessons were judged stronger. These classifications were made on the basis of how well teacher lessons matched the TeL Project’s recommended approaches and, more generally, by evident characteristics of constructivist learning environments (Bransford, Brown, & Cocking, 2000).

Weaker lessons in mathematics. Some teachers incorporated teaching practices recommended by TeL—such as having students work in groups and carrying out investigations designed around relevant contexts—and there was awareness of the importance of sharing. However, the investigations were sometimes poorly structured or were procedural learning disguised as constructivist learning, and many questions asked by the teacher dealt with superficial aspects of the mathematics. Other teachers showed no change in approach between our first and second observation and, in fact, employed methods that were in conflict with the ideas presented in TeL. One prepared and taught lessons that focused on less important mathematical activities for both sessions. Another used a very traditional approach by describing step-by-step what students are to do rather than giving them an opportunity to explore various solutions. A third used group work at both sessions, but students worked on a disconnected set of problems/tasks and there was no attempt to draw students together to discuss strategies or build mathematical connections.

Stronger lessons in mathematics. Three teachers used the probability game they had created for the program; a fourth chose a game from the student text, noting that he had not used the activity the year before but had recognized its value after participating in the program. Although teachers did not fully capitalize on the potential of the games to help their students make mathematical connections, they did demonstrate a budding awareness of the following: that an activity must be carefully planned and orchestrated; that it is necessary to consider possible student difficulties during planning; and that the opening of the lesson needs to connect to prior knowledge and provide students with skills for the activity. Another teacher moved from direct teaching to a much more open style, and at the second observation talked about her new appreciation for letting students struggle with an idea. She said that the TeL experience " . . . opened her eyes to not being so teacher-directed in the classroom." A teacher who was already confident and knowledgeable, showed in the second observation that she had moved from having students share what they did, to having them compare and debate approaches. A final teacher in this group taught an adequate but unfocused first lesson. Her second lesson was much more tightly organized and effective. She commented that the TeL Project had made her see teaching math as a priority, and had helped her reflect on her teaching practice.

*Weaker lessons in science/technology.*_In these lessons, all teachers employed at least the opening and extended middle of the three-part lesson (described earlier): the concluding part was either missing or fairly weak. Typically, classes would end with a promise that there would be a follow-up discussion during the next lesson. We observed one teacher who had gone to considerable trouble to obtain materials, in this case, three ray boxes, and three mirrors for a demonstration. Although the lesson was very procedural, it clearly (to the teacher) represented a big step forward as it was the first time she had made the effort to acquire specific science/technology materials. In another class we visited, the teacher had invited us to view her students' work for a science fair project. We noted that much of the students' project work was "informational" and typical of what grade 3 students could produce even though the students were in grade 8. The questioning skills of teachers in this category were typically weak and devoid of anything of substance about science/technology. Questions were usually of the "Does it work?" type.

*Stronger lessons in Science/technology.*_Teachers in this category planned and executed three-part lessons well. They had become skilled at making connections with previous student learning, asking deeper level questions, and using small group hands-on activities. For example, one teacher started by eliciting prior knowledge of pendulum motion from a parallel experiment (done the previous day) that had examined the relationship between pendulum length and the pendulum. The students then began hands-on experimentation with pendulums. During the class, the teacher circulated to groups and assisted them in problem solving. She asked for answers but also asked why certain results had been obtained and why and how students chose to carry out tasks as they did. She also held impromptu brainstorming sessions involving the whole class during the course of the lesson. After about 25 minutes of experimental activities by the students, the teacher halted the class and began whole-group questioning. She probed their understanding of what it means to make a prediction: "When I ask you to fill in your prediction, what am I asking you to say—what is it exactly about?" Student: "What you think is going to happen, like what string length will have more swings." Teacher: "Yes—am I looking for descriptions of the strength of the thrust?" Student: "No . . ." The teacher then spent a few minutes clarifying the measurement of the angle to the plum line, asking the class for measurements of the 90- and 45-degree angles she demonstrated.

RESULTS-IMPACT ON STUDENTS

We examined the impact of the TEL Project on students, the fifth level of Guskey's (2000) framework, by analyzing student attitudes and perceptions toward it and by summarizing teacher comments of how students reacted to it. The mathematics results are presented first, followed by science/technology.

Student views of mathematics

We compared the results of the pre- and post-program student surveys to see how students' attitudes and perceptions toward the two subjects changed over the course of the professional development programs. Responses to 25 questions had statistically significant pre-post differences ($N=427$). The questions are readily grouped into four categories: time spent on mathematics; the mathematics classroom; value of mathematics; and succeeding in mathematics. We report pre-post differences between students from high- and low-SES schools only when they are statistically significant ($p<.05$).

Time spent on mathematics. Students differed between the beginning and end of the program on three questions related to time spent on mathematics. On post-surveys, students reported spending *less time* working on mathematics weekly (p=.009) and *less time* daily on homework (p=.007). They also reported spending less time daily on other subjects as well (p=.005). Analyses of these data by SES revealed that at the end of the program, high-SES students reported spending significantly *less time* on mathematics work in one week than low-SES students (p=.020); *less time* studying mathematics or doing mathematics homework after school (p=.012); and *less time* on other school subjects (p=.004).

Table 3. Student Pre-Post Responses about the Mathematics Classroom (N=427)

	Question	Survey Mean		p
		Pre	Post	
8a	In my mathematics class students often work using a textbook. (Strong agree=1 to Strongly disagree=4)	1.96	2.06	.007
8b	In my mathematics class students often work from exercise sheets to practice what the teacher has taught. (Strong agree=1 to Strongly disagree=4)	1.88	1.78	.010
8c	In my mathematics class students often work on projects. (Strong agree=1 to Strongly disagree=4)	2.57	2.78	.000
19b	When we begin a new topic in mathematics, we begin by discussing an example related to everyday life. (Almost always=1 to Never=4)	2.40	2.24	.003
19f	When we begin a new topic in mathematics, we begin by trying to solve an example related to the new topic. (Almost always=1 to Never=4)	1.98	1.81	.001
20q	How often…do students write on the board. (Almost always=1 to Never=4)	2.61	2.49	.013
20c	How often…do you have a quiz or test. (Almost always=1 to Never=4)	1.87	1.79	.064
9a	In my mathematics class most of the students do their homework. (Almost always=1 to Never=4)	1.98	2.07	.008
20k	How often…begin homework in class. (Almost always=1 to Never=4)	1.62	1.53	.042
20j	How often…teacher checks homework. (Almost always=1 to Never=4)	1.66	1.79	.006
20g	How often…use computers. (Almost always=1 to Never=4)	3.40	3.31	.045
16b	How often used the World Wide Web to access information for mathematics projects. (Almost always=1 to Never=4)	2.94	3.11	.003
20f	How often…use calculators. (Almost always=1 to Never=4)	2.38.	2.04	.000
20p	How often…teacher uses an overhead projector. (Almost always=1 to Never=4)	2.53	2.70	.001

The mathematics classroom. Responses to questions 19b and 19f in Table 3 suggest that teachers were trying to make the mathematics classroom more relevant to students as more students agreed at the end than at the beginning that new topics were introduced with examples of the relevance of the topic. At the completion of the program, students reported doing less textbook work (Q8a) and more exercise sheets (Q8b), although low-SES students reported using textbooks more often than high-SES students (p=.008) by the end of the program. Project work seemed to have dropped off at program's end (Q8c), but student writing on the (chalk/white) board increased (Q20q). Students perceived that they wrote more quizzes and tests at the end of the program than at the start (Q20c).

As for homework, students reported that at the end, they had a greater opportunity to begin the homework in class (Q20k), and that their teacher checked it less often (Q20j). Whether as a consequence of reduced teacher checking or not, *fewer* students appear to agree with the statement in question 9a that most students in the class do their homework.

Students appeared to be using computers and calculators *more* at the program's end than the beginning (Q20g and Q20f), although high-SES students used calculators more often (p=.002) by the end of the program. The Web seemed to be used *less* for mathematics projects than before (Q16b); teachers were also using the overhead projector less (Q20p).

Value of mathematics. Unfortunately, students overall did not seem to value mathematics as much at the conclusion as at the beginning. Fewer students agreed with statements that mathematics is important in their lives (p=.045) and that it is important to do well in mathematics to please themselves (p=.038). Also disheartening is the fact that more students agreed at the end than at the beginning with a statement that mathematics is boring (p=.019). The one positive sign is that significantly more students at the end of the program responded that it is important to do well in mathematics at school (p=.014); however, very significant SES effects were found (p=.000), indicating that more low-SES students than high-SES students agreed with this statement at the end of the program than at the beginning.

Succeeding in mathematics. Significantly more students disagreed at the end than at the beginning that in order to succeed in mathematics, you need lots of natural ability (p=.039) and good luck (.035). More *disagreed* at the conclusion of the program that to do well you need to memorize the textbook or notes (p=.007), which may suggest that more students see that understanding is an important aspect of success in mathematics.

Teacher views of changes in mathematics students

In the evaluation forum, teachers made comments about students in two areas: activities students enjoyed and changes they noticed in the attitudes and abilities of students.

*Enjoyment of mathematics activities.*_Geometer's Sketchpad (Key Curriculum, 2007), a popular mathematics exploratory software package, which no teachers had used before, was highlighted as an appealing tool for students. Teachers commented that it allowed students to work at their own pace and have fun; they felt that students were very engaged with this program and were "laughing" in math class. Overwhelmingly, this was something students enjoyed using. Students also enjoyed using tangrams and manipulatives like geoboards, which allowed them to see the "why" of mathematics—and teachers noted that their students were more successful both during and after the lesson in retaining their learning when these were used. Classes enjoyed taking an online student survey about their opinions of mathematics that was given by teachers as part of the program. In general, there was an increased receptivity to mathematics on the part of students; teachers attributed this to the fact that their delivery was making mathematics more fun and engaging for a diverse group of learners.

*Changes in mathematics attitudes and abilities.*_Teachers noted better engagement from students with lower mathematics skills, as well as improvements in students' self esteem, motivation, and attitudes. They spoke of increased student enjoyment of mathematics: they felt that students took greater pleasure from the lessons, and this in turn led to better student focus during the lesson, more self management by students, and a greater willingness to take risks. Of particular note were comments that indicated that learners with attention deficit disorders and learning disabled students were benefiting by being able to focus for longer periods of time. Also, teachers felt that there was increased learning for bodily kinesthetic learners in activities like Traffic Jam where students line up and exchange places to learn pattern recognition and generalization. Lastly, teachers felt that all learners demonstrated greater collaborative skills, higher order thinking skills, and enhanced problem solving skills as a result of their new teaching methods.

Student views of science/technology

In contrast to the large number of significant pre-post survey differences in mathematics, only four questions had statistically significant differences in science/technology (N=401). Significant changes in pedagogy between the beginning and end of the program were noted by students, with less use of worksheets (p=.002) and individual seat work (p=.025). At the same time, significantly more students reported that they were spending more time in class on hands-on activities, such as lab experiments (p=.026). This change corroborates teacher reports discussed previously that more time was being spent on active learning. Importantly, significantly fewer students viewed science/technology as their weakest subject at the program end than had done so at the beginning (p=.009).

Significant pre-post differences when analyzed by SES were found on three other questions. Compared to students in low-SES schools, students in high-SES schools reported that they worked more on projects (p=.029); felt science/technology was more important to everyday life (p=.041); and were asked more often to connect prior learning with what they knew about a new topic being introduced (p=.019).

Teacher views of student changes in science/technology

Teachers reported that, in general, improvements were noticed in both student confidence with, and a desire to learn, science/technology. Increased enthusiasm and greater interest in the subject were noted by several teachers. Teachers also observed that students were more willing to get involved with class experiments and report on their findings. Students appeared to be more engaged in higher-level thinking and problem solving. Some teachers noted that students were asking more questions, and that these questions were more in-depth, and more thoughtful in nature. Others noticed fewer behavioral comments from substitute teachers using the science/technology day plans they left behind: they attributed such changes to the fact that students were more involved in their learning.

There were mixed reports about the development of teamwork skills. Most reported an improvement of student collaborative skills. They observed that students seemed better at helping each other, especially on specific jobs related to a given task. However, teachers whose students were not used to teamwork felt that their students needed more time to develop these skills.

According to teachers, hands-on learning opened the eyes of students to new experiences, enabling them to make better connections between what they learn in school and their own lives. Many teachers also noted that students were beginning to accept more ownership for learning. They saw their role as having shifted from the "sage on the stage" to a more facilitating one, which helped create an environment that encouraged students to learn on their own. Teachers reported that the integration of hands-on experiences into their classes, coupled with a focus on design and inquiry processes, fueled a richer learning experience for students. Students became more able to make connections to other learning and experiences in everyday life. Additionally, teachers saw the inclusion of hands-on activities as beneficial to every kind of learner. In particular, students who struggled with learning disabilities or those who had English as a second language were able to contribute meaningfully when hands-on activities were employed.

Several teachers mentioned a connection between improved student grades and their own professional growth; however, most felt that they had not had sufficient time to gauge this accurately. They did, however, state that their professional development had enabled them to better help their students grasp difficult concepts.

SUMMARY AND IMPLICATIONS

The purpose of this study was to assess the impact of the TeL blended learning professional development program on teachers and students. We employed Guskey's five-level framework to delineate this impact. Next, we summarize our results across the five levels and the two programs in terms of their impact on teachers and students. In doing so, we compare and contrast the outcomes of the programs and draw out implications for the design of blended learning professional development programs in general.

Teacher impact

What was clear across both programs was the high level of teacher satisfaction with the professional development experience with which they were provided. Added to this, teachers appeared to gain the confidence needed to experiment with new pedagogical approaches in their classrooms and to share and reflect upon their successes and disappointments with their colleagues. In itself, this is a significant accomplishment of the program as confidence development is a key component of in-service teacher learning (Graven, 2003). The opportunity for teachers to learn on the job, focus on the curriculum which they are expected to teach, and share with peers over an extended period of time are well recognized in the literature as key aspects of professional growth (Hiebert et al., 2002; Mundry, 2005).

A closer examination of the teacher satisfaction data indicates that much of the satisfaction stems from the face-to-face sessions, which teachers enjoyed and looked forward to. Mixed feelings were expressed in terms of their satisfaction with the online component. On the whole, teachers did complete their weekly online assignments; however, reflective journal writing tapered off in both programs to where just over half of the teachers submitted two or more journals by program mid-points. This occurred even though teachers were provided with teaching release time to do this as well as other program-related assignments and activities. The journal participation rate did not improve in the second year despite scheduling the program to avoid peak work periods for teachers.

The training of facilitators during the second year was deliberately undertaken with the intent of improving the quality of the online discussion and journal submission as skilled facilitation is critical for increasing the participation and quality of the online experience (Salmon, 2003). Evidently facilitator skill was either insufficient to motivate teachers to participate or teachers simply gave online activity lower priority over trying out new approaches in their classrooms.

Although teachers were very satisfied with the program overall, their feelings about how well it prepared them to teach the provincial curriculum varied between the two groups of teachers. According to survey responses, by the end of the program mathematics teachers felt significantly better prepared to teach only one topic (Probability) out of eleven covered in the program, whereas science/technology teachers felt better prepared to teach three out of four key strands. This finding was somewhat surprising considering that the mathematics program was eight weeks longer than the science/technology program. The only explanation we can deduce is that the relatively weak subject area backgrounds of the mathematics teachers, as described earlier in this article, prevented them from benefiting from TeL even with the additional program length. This finding suggests that developers need to be more aware of teachers' prior content knowledge and plan programs so that teachers can learn the content that they will be teaching in ways that are linked to the classroom (Cohen & Hill, 2001; Loucks-Horsley et al., 2003; Ma, 1999). The need for this is more critical for the online portion of blended learning programs than the face-to-face part. This is because it may take developers more time to realize teachers' subject-matter weaknesses as they do not receive the immediate feedback from participants that they would get in face-to-face sessions. Additionally, it may be more difficult to modify the online portion of a course while it is in progress because participants may be at different stages in their progress through the course at any given time, so modifying sections that some have already completed would not be desirable.

The TeL program did appear to affect teachers' beliefs and practices. The most significant pre-post change of all survey questions in both programs was the one that dealt with whether it is acceptable to leave students puzzled at the end of a class. More said that it was acceptable to do this, which suggests that teachers may have been teaching mathematics and science/technology in a more open-ended, constructivist way by the end of the program. Both mathematics and science/technology teachers' responses suggested that they became more skilled in questioning and had students work in groups more often. Beyond this, science/technology teachers reported shifting from whole-class lecturing and demonstrations of straightforward content to open-ended, student-centered classes where students design, discuss, and report on their own experiments. They also became more creative in teaching with everyday materials and not having to rely on scarce lab equipment. Our classroom observations confirmed that these changes were occurring and that more changes occurred in the science/technology classes than in the mathematics classes. Again, the most plausible reason why the mathematics teachers did not change their practice as much is because of their weaker backgrounds, because teachers with weaker content knowledge tend not to feel comfortable teaching higher-order thinking skills and engaging in related practices, such as hands-on learning (Wenglinksy, 2000).

For the most part, teachers in the TeL program were well-supported by their schools. The most significant barrier teachers faced was finding adequate time to complete all that was expected of them in the program. Indeed, time for professional development is a key issue that arises from most studies of school change (Fullan & Miles, 1992; Garet et al., 1999). TeL was one of the most generous professional development programs we have seen in terms of supporting teachers with teaching release time. In fact, so much time was available that teachers did not want to make use of all of it because they felt that their students would suffer from them being absent so often. Teachers were faced with a moral choice: should they take more release time to devote to the program so that they can improve their teaching skills while recognizing that their students might suffer, or should they forgo release time and let the TeL program slip so that the students will benefit from their greater presence? Therefore, the resolution to the issue appears to be not just providing adequate time, but helping teachers spend and allocate available time (Loucks-Horsley et al., 2003). Teachers in TeL were generally not used to self-directed professional development as it was normally something "delivered" to them. This implies that in the less structured online portion of a blended learning program, teachers may need more help in planning, allocating, and using the time available to them.

Impact on students

There were more pre-post differences on the student survey for mathematics than for science/technology, although the changes were not all for the better. Fewer students believed that mathematics is important in their lives and that it is important to do well in mathematics to please themselves. Also discouraging is that more students agreed at the end of the program than at the beginning with a statement that mathematics is boring. This finding is surprising as teacher reports suggested that students had become more motivated and engaged in their mathematics work; however, in the context of the literature on student motivation, the middle-school years are when students often exhibit a downward trend in motivation and increase in negative attitudes about schooling (Anderman & Maehr, 1994). Other aspects of the classroom that students reported had changed, such as the teacher linking a new topic to past work and everyday life, were confirmed by teachers.

The equivalent student questions for science/technology about whether the subject was boring or not, and its importance in their lives did not reveal any significant pre-post differences. In fact, science/technology students' attitudes appeared more positive at the end of the program because fewer students felt that it was their weakest subject. Teachers confirmed that science/technology students thought more positively about the subject by the end of the program. Students reported an increase in hands-on activities such as experiments occurring in their classrooms, something which teachers also said happened.

Several interesting differential effects were found when comparing the pre-post differences of students from high- and low-SES schools. More low-SES students than high-SES students agreed that it is important to do well in mathematics at school by the end of the program than at the beginning, which suggests that low-SES students tend to benefit at least attitudinally from the hands-on, student-centred mathematical activities that teachers were employing. This finding contradicts Chall's (2000) summary of empirical literature which suggests that low-SES students may be negatively affected by student-centered approaches.

No pre-post differences were found for science/technology students on the same question, however high-SES science/technology students felt that the subject was more important to everyday life by the end of the program. Other differential effects we found were that high-SES mathematics students reported using calculators more; they spent less time on mathematics work in one week; less time studying mathematics or doing mathematics homework after school; and less time on other school subjects. For their part, high-SES science/technology students reported working more on projects and were asked more often by their teachers to connect prior learning with what they knew about a new topic being introduced.

Implications for research and practice

At this point, very little use has been made of the blended learning model in K-12 teacher in-service programs, despite its rise in popularity worldwide (Bonk & Graham, 2006). Currently, the model is being employed in formal, accredited pre-service programs offered by schools of education (Khine & Lourdusamy, 2003; Kupetz & Ziegenmeyer, 2005), general university degree programs (Twigg, 2003), and in training for industry (Lewis & Orton, 2006). This study describes a blended learning program professional development program that was developed to enhance the pedagogical skills of middle-school mathematics and science/technology teachers. Blended learning programs such as the TeL Project provide teachers the opportunity to meet in intense face-to-face sessions and share their thoughts and successes and learn about improving their practice online in between these sessions. Since the model reduces the need to bring teachers together as often at a central location as done in traditional district-wide professional development, it can potentially lower a district's costs, particularly if an online learning system is already in place.

More research, preferably controlled experimental studies, is needed to assess the general utility of the blended learning model before widespread adoption for professional development. Our study suggests several specific aspects of the model that need to be explored. Two of these are the nature of the online tasks given to teachers as part of the program, and the role of the online facilitators. In this program we saw that teachers were more motivated to post online reflective journals if they got helpful feedback from facilitators. We suggest that shorter weekly postings on teacher reflections in a course discussion forum may be more stimulating, rather than the lengthier and less frequent reflective journals required in the present program. Facilitators need to be skilled at responding to these postings and encouraging group discussion on topics raised by other teachers in the group. Secondly, as discussed earlier, program designers need to take into account more carefully teacher subject-matter expertise when designing their programs, because once a blended learning program has begun, more complications arise than in a face-to-face program when it comes to adapting it once it is already underway. Third, researchers should plan to assess the impact of blended learning professional development on student achievement. Our study did not do this, however teachers suggested that it was probably premature in a program of this length to expect a positive impact on achievement. Thus, researchers are likely going to need to design studies of at least a full-school year in length in order to obtain a measurable impact on achievement. Finally, the TeL Project gave teachers more release time than is financially feasible for most school districts. Researchers will need to study implementations of blended learning programs that have less teacher release time than the present one to determine if outcomes differ.

Notes

1 The Ontario curriculum combines science and technology into one subject, which is referred to in this article as science/technology. Science includes what is traditionally taught in science at this level; technology deals with the application of knowledge to meet an identified need or solve a specific problem using materials, energy, and tools. Science/technology is described in the curriculum as not only a body of knowledge but "a way of knowing."

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