Final Report on the

Evaluation of the Science and Technology Program

of the Teacher eLearning Project

by

Ron Owston, PhD

With contributions from

Ray Bowers, Jane Kennedy, Margaret Sinclair, Ken Stief, Herb Wideman

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Executive Summary

The Learning Partnership's Teacher eLearning (TeL) Project provided a professional learning experience for grade 6, 7, and 8 science and technology teachers in two Toronto school boards during the 2004-2005 school year. This blended learning program, which combined periodic face-to-face day sessions with weekly online discussions and activities, was the second of two planned professional development initiatives. The previous school year the focus was on mathematics teaching.

This document reports on evaluation findings of the science and technology program in five main areas: (1) the program's impact on teachers; (2) its impact on students: (3) its impact on students of different socio-economic (SES) backgrounds and abilities; (4) other intended and unintended effects of the program; and (5) issues related to the program's sustainability and transferability. The evaluation methodology included pre- and post-program surveys of participating teachers and their students, classroom observations, interviews of teachers, principals, program leaders, supervisory officers, and program facilitators, and analyses of online activities.

Findings clearly indicate that the TeL science and technology program was successfully implemented. With regard to teacher changes, we found that teachers: viewed the program as a valuable professional learning experience; gained confidence to experiment with hands-on activity based learning; used more higher level questioning; tried out new kinds of teaching materials; provided students with greater autonomy for designing projects; grouped students more in mixed ability teams; and increased their subject matter knowledge. Students, too, appeared to have benefited from their teacher's participation in the program: they became more engaged and motivated to learn science and technology; their overall views on the importance of the subject became slightly more positive; and they took more ownership of their work.

Several distinctions were found between different types of students from beginning to end of the program. Of particular interest were the changes in attitude toward science and technology between different SES schools: students from low SES schools viewed science and technology as less important to everyday life by the end of the program, while students from high SES schools viewed it as more important. One explanation for this disconcerting trend for students in schools with a low SES could be that they came to view science and technology as a series of play activities (e.g., making a paper airplane), rather than a serious academic subject. More encouraging was that the science and technology program activities appeared to be especially beneficial for ESL and special education students who became more engaged than they normally would have been in the subject.

Some aspects of the program require further attention. Despite responding to recommendations of the mathematics report that the program be shortened and rescheduled to avoid traditionally busy times, teacher workload continues to be an issue. Many teachers found the program demands excessive even though they received the same amount of release time as the mathematics teachers last year. Both the online and face-to-face components require additional refinement. The design of the online component needs to be examined for ways to better facilitate teacher engagement and develop a stronger sense of community among teachers. Teachers perceive the face-to-face sessions as attempts to introduce a considerable amount of content, at the expense of teacher interaction, where valuable teaching ideas could be shared.

Although the blended learning model employed in this project is successful, concern was raised about the cost of sustaining the current version due to the high cost of teacher release time.

We present nine recommendations to enhance the program should it be offered again. They are:

1. Ensure that the course expectations are clearly communicated to principals.
2. Review the structure of the online sessions in order to develop a greater sense of community among teachers and a stronger focus on student work.
3. Enhance the training of facilitators.
4. Consider extending the length of the day for face-to-face sessions.
5. Consider altering the organization of the face-to-face sessions.
6. Provide suggestions to principals on how to make better use of teachers who participate in the program.
7. Engage program developers in a discussion about how the differential student effects of the program can be addressed.
8. Encourage boards to support a special electronic community for science and technology teachers.
9. Continue to encourage boards to plan for and adopt the summer institute model for the future professional development programs.

The report concludes with an epilogue that provides comparisons of the science and technology program with the mathematics program. The comparisons are presented in tables that give quotations from this report and the mathematics report regarding our findings on teachers, students, and the program's differential effects on students.

Table of Contents

Final Report on the
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1. Introduction

The Teacher eLearning (TeL) Project offered by The Learning Partnership is aimed at enhancing the skills of grade 6, 7, and 8 teachers of mathematics and science/technology. It is a blended learning experience that combines periodic face-to-face day sessions with weekly online discussions and activities for the purposes of professional development. The mathematics program ran from September 2003 to April 2004, and the science and technology program ran from September 2004 to February 2005. A separate evaluation report was produced last year for the mathematics program.

This document will report the evaluation findings of the York University research team on the TeL science and technology program. After outlining the evaluation methodology, we will address the findings on each of the main evaluation questions. These questions are as follows:

1. What impact did the project have on teacher confidence and capability in creating an engaging classroom environment for their students for the teaching of science and technology?
2. What was the impact of the program on students as demonstrated by their classroom engagement and perceptions about science and technology?
3. Did some students benefit more from the program than others?
4. What other issues arose in the science and technology program?
5. How can the project be sustained beyond its formal end and transferred to other settings?

After our findings are presented, we will then offer a summary and recommendations based on this year's program. The report will conclude with an epilogue containing comparisons between this year's program and the mathematics program.

2. Evaluation Methodology

A variety of data collection activities were performed, including: teacher and student surveys, key informant interviews, classroom observations, and online discussion monitoring. These data collection activities are summarized in Table 2.1 below.

Table 2.1 Evaluation data collection activities during 2004 and 2005

ACTIVITY	DESCRIPTION
Administered Teacher Surveys	**2004**: The pre-program teacher survey was completed in September on orientation day. Sixty-five teachers responded.
	2005: The post-program survey was administered during the final face-to-face session in February. Due to low attendance, the deadline was extended until March 31. A total of 35 teachers responded.
Administered Student Surveys	**2004:** A total of 942 students completed the pre-program student survey during October and November.
	2005: Teachers began administering the post-program survey to their classes in February, but, because of March break and computer access difficulties, the deadline was extended until April 8. There were 551 responses.
Interviewed Key Stakeholders	**2004**: As per the original research plan, no interviews were scheduled; however, the Learning Partnership TeL coordinator was interviewed, as he was new to the position.
	2005: Individual telephone interviews were conducted with two Learning Partnership managers, nine principals of participating schools, three school board supervisory staff, and all four facilitators.
Conducted Classroom Observations	**2004**: We observed 16 teachers from two school boards. From **high SES** schools: grade 6 (two teachers), grade 6/7 (two teachers), grade 7 (one teacher), grade 7/8 (one teacher), grade 8 (one teacher). From **low SES** schools: grade 6 (two teachers), grade 7 (two teachers), grade 8 (five teachers). Although the number of classes in the grades for each SES level was unequal (due to difficulty in getting teachers to commit and logistical issues), we observed at least one teacher at each grade for each SES level.
	2005: We asked teachers we observed in the Fall if we could return in March. Because of March break and scheduling difficulties, we did not finish observing teachers until mid-May.
Conducted Evaluation Forum	**2005**: We interviewed participating teachers in six groups during the January face-to-face session that launched the second module.

Online Session Monitoring	Throughout the program online discussions were monitored. Teacher online journal entries for Module A were compared with Module B to look for reported changes in attitudes, perceptions, and practices.

Survey Instruments

The teacher and student surveys were adapted for science and technology from those used for the mathematics program last year. Many questions on the teacher survey were originally drawn from one developed by Kennedy, Ball, and McDermott (1993). The student survey on attitudes and perceptions toward science and technology was based on the *Science Work Experience Programs for Teachers* (SWEPT) project (see http://www.sweptstudy.org/), and supplemented with some items from the student survey portion of the *Repeat of the Third International Mathematics and Science Study* (see http://timss.bc.edu/timss1999i/questionnaires.html).

Data Analysis

All survey data were tabulated and statistics generated using SPSS software. A repeated measures analysis of variance design was used to compare pre- and post-program survey results of teachers and students. All interviews, including those done during the evaluation forum, were tape-recorded and most were transcribed. Common themes and patterns were identified in the interview transcripts, in some cases, with the assistance of the Atlas.ti qualitative data analysis software package. Similar techniques were employed for the online journals and classroom observation notes.

3. Findings on Teacher Effects

Evaluation Question 1: *What impact did the project have on teacher confidence in creating an engaging classroom environment for the teaching of science and technology?*

In order to address this first question, we examined data from the teacher survey, teacher journals, classroom observations, and from principal, superintendent, and project implementer interviews.

Who were the teachers in the project?

Sixty-five teachers attended the September project orientation day and completed the online survey. However, a small number attended to "test the waters" and subsequently decided not to participate. Early in the Fall there were some additional dropouts and some new participants added. In January there were another five dropouts. Thirty-five teachers completed the final survey, however, two of the teachers completed the open-ended questions at the end of the survey only as they had not taken the September survey. This left 33 valid responses for pre-post survey comparisons.

According to the final teacher survey, the ratio of female to male participants was 76% to 24%, whereas in September the ratio was 65% to 35%. This suggests that proportionately more male teachers dropped out than female teachers. Out of the 33 participants who completed the survey, 76% held bachelors degrees, 21% held master's degrees, and 3% held a doctoral degree in science. Thirty-nine percent of the teachers had either a science minor or major, 18% had graduate level science, 25% had taken some university science courses, and 18% had OAC/grade 13 high school courses in science. Unfortunately, disproportionately more teachers from the latter two categories dropped out, as they comprised 61% of the group in September but only 43% by program end.

Overall teachers were very satisfied with the program, as 56% said that the program fully met their expectations and 44% said that it met expectations to some extent. Of note: none felt that the program did not meet many or any of their expectations.

What changes in views did teachers report on the survey?

To answer this question, pre- and post-program survey responses were compared for all 33 teachers who completed both surveys. Responses to 18 questions were found to be statistically significant, indicating that the teachers' views on these items changed during the program more than one would expect by chance alone. Without a comparison group of non-participating teachers, it is difficult to say whether observed changes were a direct result of the program. Nevertheless, given the nature of the changes that did occur, one can hypothesize that the program was likely the most significant event that occurred during the school year to have affected teachers' perceptions of science and technology. The questions with the most significant pre- and post-program differences are given in Table 3.1 below and are clustered into four groups according to question topic. For the sake of readability, the non-significant responses are not presented in this section. A copy of the teacher post program survey with response frequencies for all questions is given in **Appendix A**.

The first cluster of significant changes is centred on teacher beliefs about teaching science and technology, and is given in Table 3.1. The most significant change was found for question 11a. At the start of the program teachers tended to maintain that students should never leave a science and technology lesson feeling confused or stuck. This belief is based on a traditional view of science as a body of facts and concepts that need to be mastered. By the program's end, teachers tended to feel that it is not unacceptable if students leave a lesson confused or stuck. This change in viewpoint reflects the program philosophy that advocates the learning of science and technology as a fluid process; that answers and results are not always straightforward and may not always meet expectations. The program's philosophy was also reflected in teacher beliefs about how science and technology could help sensitize students to societal issues and values. As shown in question 5c, by the end of the program, significantly more teachers agreed that these subjects are an ideal way to develop such sensitivities.

The remaining two questions can be seen to also positively reflect the program's influence. Question 4f shows less emphasis being given to rote learning of rules and, by implication, more emphasis being placed on the understanding of processes by the end of the program. Question 11g suggests that teachers valued mixed-ability student grouping more at the end of the program.

Table 3.1 Survey questions on teacher beliefs with significant pre-post program differences (N= 33)

No.	**Question**	**Survey Means[1]**		**P[2]**
		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
5c	Science and technology is an ideal way to develop sensitivities on societal issues and values. (Strongly agree=1 to Strongly disagree=5)	2.28	1.91	.008
11a	Students should never leave a science and technology lesson feeling confused or stuck. (Strongly agree=1 to Strongly disagree=5)	2.91	3.61	.000
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

[1] Note: when comparing pre- and post-means, a lower mean value indicates stronger agreement with the statement and vice versa.

[2] p=probability of difference occurring. When $p<.05$, it is assumed that the difference is not due to chance alone.

Table 3.2 shows the significant pre-post program differences in the second cluster, which deals with teacher practices. As with the previous cluster, all of these reported changes in practice would appear to reflect the positive influence of the program on teachers. Questions 6c and 6d suggest that by the end of the program, more open-end problems were being assigned to students and there was a greater use of computers. 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) and more time having students design their own experiments (8a), and giving fewer lecture style presentations (8c). They also appeared to be using 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).

Table 3.2 Survey questions on teacher practice with significant pre-post program differences (N= 33)

No.	**Question**	**Survey Means[3]**		**P**
		Pre	**Post**	
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

[3] Note: for questions 6c, 6d, 7e, 9h, and 18 a higher mean indicates that the practice occurs *more* often; for all other questions a higher score indicates it occurs *less* often.

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

The third cluster, shown in Table 3.3, deals with homework and assessment. The results suggest that teachers were spending less time reviewing homework (8i) than they had previously. This was not a practice suggested during the science and technology program, but it is possible that teachers asked students to review each other's homework, or because more project-based classroom work was being undertaken, less homework was assigned. Question 15d suggests that by Spring, teachers were giving less weight to short answer or essay tests. This could also be as a result of more project-based classroom work being assigned.

Table 3.3 Survey questions on homework and assessment with significant pre-post program differences (N= 33)

NO.	**Question**	**Survey means**		**p**
		Pre	**post**	
8i	How often do you spend time on reviewing homework? (Very often=1 to Almost never=4)	2.45	2.76	.023
15d	Weight given in assessment to short answer or essay tests that require students to describe or explain their reasoning. (A lot=1 to None=5)	2.28	2.63	.019

Table 3.4 shows the final cluster of significant pre- and post-program changes. Four questions were asked on how prepared teachers were to teach different areas of the science and technology curriculum. Teachers indicated that by the end of the program, they felt better prepared to teach Life Systems, Earth and Space Systems, and Matter and Materials than they had originally. The fourth area where there were no significant pre-post differences was the strand on Energy and Control.

Table 3.4 Survey questions on teacher preparedness with significant pre-post program differences (N= 33)

NO.	**Question**	**SURVEY MEANS**		**p**
		PRE	**POST**	
16a	Prepared to teach Life Systems. (Very well prepared=1 to Not at all prepared=5)	1.76	1.45	.010
16d	Prepared to teach Earth and Space Systems. (Very well prepared=1 to Not at all prepared=5)	1.97	1.67	.010

16e	Prepared to teach Matter and Materials. (Very well prepared=1 to Not at all prepared=5)	1.97	1.61	.005

At the end of the survey teachers were asked to specify what new knowledge and skills they gained from the course. Most teachers said that they either learned how to apply Higher Order Thinking Skills, or the HOTS model specifically, or, how to apply inquiry and design more generally to science and technology teaching. Another predominant theme found was a move away from conventional modes of risk-aversive directed teaching to a greater willingness to take chances, explore new options, and give students more leeway to explore and learn from failures.

What were teachers' reflections on practice?

Teachers posted journals regularly throughout the program in which they reflected on their experiences. Two themes were evident when they wrote about the impact of the program on their teaching: the three-part lesson and the incorporation of HOTS.

The three-part lesson was, for the most part, viewed as a tool for greater organization, planning, and ultimately learning, for both teacher and student. Teachers identified this approach as being one they had had prior experience with when in Teacher's College and one respondent commented on their experiences with its use in a provincially mandated lesson plan in BC. While many teachers did not like the time consuming nature of this planning technique for lesson delivery, it was pointed out by more than one participant that the more often this technique was used, the easier the lesson plans become to write, plan, and implement. One teacher also identified the link between the three-part lesson and the current Provincial document *Think Literacy: A Cross Curricular Approach*.

The other topic of discussion in teachers' journals was HOTS. Some participants wrote about liking the idea of beginning their classes with a thought provoking question or idea; others wrote about their strategies to encourage students to relate the science and technology they were learning to world issues and everyday experiences.

While all teachers were in agreement about the need to promote higher order thinking skills in their learners, there was little agreement about how often HOTS questions should be used in teacher's programs, or if these questions could adequately meet the needs of all students. Some teachers were wary of incorporating HOTS questioning on a regular basis, while others were ready to make HOTS a priority in their lessons—not only science and technology, but in other subjects as well. Overall, the majority of teachers supported the use of HOTS and the development of critical thinking skills despite feelings of trepidation. A typical sentiment is seen in this journal entry:

> *I can be sensitive to the fact that critical thinking often comes from topics that teachers may find themselves unprepared to discuss as well as taking time away from the curriculum. This can only be overcome when teachers are given the support that they don't always need to be 'right' and that they need to focus on the curriculum but not live by it.*

Teachers who identified themselves as seasoned veterans of the approach shared that the key to success was to create activities that disguised critical thinking as "fun," thus getting students to use HOTS without being aware of it. They cited this as crucial to eliminating the familiar “I can’t do that” factor. One teacher below describes such a defeatist attitude:

> *There are some negative points also which I have observed in my class. Some students think: it can’t be done. This attitude is, in effect, surrendering before the battle. By assuming that something cannot be done or a problem cannot be solved, students become the victims of the “I can't do it” or “There's nothing I can do” factor. Some students think, well maybe the problem can be solved by some expert, but not by me because I'm not smart enough to solve such problems. But, on the other hand, HOTS could explore students’ hidden talents, after all the Wright brothers thought they could invent an airplane, and they were not Aviation engineers, they were bicycle mechanics.*

Many teachers placed high value on the importance of “play” in teaching—students must be allowed to have fun while learning. They felt that design activities worked well to achieve both the goal of having fun and promoting HOTS.

While many teachers were enthusiastic about the learning their students could achieve with HOTS, there was unanimous agreement that HOTS takes time to develop: it requires a lot of practice for both teacher and students, and the lessons/activities take much time to prepare. It was also expressed that students require a certain amount of base knowledge or prior experience in order to engage in HOTS successfully.

A number of teachers shared HOTS activities and/or tips for success in their journals. Several identified the benefits of using co-operative group structures. Working in pairs or small groups on HOTS activities/challenges was seen to promote teamwork and led to greater student success, particularly if students of differing abilities were grouped together. One teacher observed:

> *The most important, I think, is getting kids to think and finding interesting and motivating ways to do so. I also think that it is equally important that we expect all students to do the thinking, and not just the naturally bright ones. It is a skill that needs to be explicitly taught and practiced.*

Overall, a desire to enable students to become engaged, thinking members of society, able to respond to the media with a critical eye, and to question scientific and technological advances and phenomena, was clearly evident amongst teachers in the program.

Changes reported by teachers in the evaluation forum

The evaluation forum gave teachers an opportunity to reflect in small groups on how they had changed as a result of the program and to share their thoughts with the evaluation team.

> *We all agreed…that yes, [the course] did change what we felt good science and technology teaching to be. We were exposed to many new ideas, different ways of looking at things, different ways that lessons can be presented, and activities for the students. And people have tried these activities in their classroom already and the same enthusiasm that we saw in ourselves here [at the face to face sessions] was taken back to the class and that was exciting.*

This quote speaks to many of the changes cited by teachers during the forum. Reported changes included exposure to new theories of teaching science and technology, increased confidence in the delivery of science and technology lessons, greater use of hands on activities in the classroom, and familiarity with student-centred assessment in science and technology.

Participants shared an appreciation for the investment made in their professional learning. Many teachers felt that because they were less intimidated by technical topics, they were able to think twice about how science and technology lessons were delivered. Specifically, less reliance was placed on textbooks and less emphasis was put on getting the "right answer." Instead focus was put on the process of having students cultivate an answer.

Teachers reported that the program helped build their confidence. Those who felt initially inept in their teaching abilities with regards to science and technology became comfortable not only with the content of the topics in the program, but also with unit and lesson planning, and delivery. Participants felt that the course had been an eye-opening experience; it taught how to engage students, and its emphasis on the practice of good pedagogy exposed participants to new possibilities. As was pointed out by one respondent, the concepts of inquiry and design are paramount to teaching science and technology effectively, and teachers who are not "scientists" need to be taught about how these processes come to be. Inquiry-based, student-centred, hands-on, problem-based learning is new to many teachers; the program has helped teachers to achieve lessons in which their students could become fully engaged. There was widespread praise for the program's skills-based approach (versus a knowledge-based approach) and awareness that despite the fact that few students will go on to be scientists, they will carry forward the skills of problem solving, co-operative learning, and teamwork. Two quotations from participating teachers illustrate this impact:

> *I think this project has fostered some professional learning for [me] in two ways: I have learned a lot of new science and technology knowledge and skills through the different resources that were presented at the project. As well I've learned new innovative curriculum ideas through the whole designing inquiry process that we learned during the face-to-face sessions.*

Another stated:

> *I think that there is definitely increased student involvement and engagement in the lessons. I think the biggest thing that I noticed was me not telling them the answers and making them come up with the answers and their questions by themselves, and by coming up with questions as to why something might be they actually learn more… I found myself letting go of the reins and letting them discover actually benefited them… they definitely were more engaged in the approaches that I took. I think the kids have appreciated that I have taken more risks this year…*

Mastering the creation and delivery of a constructivist science and technology lesson is something that takes practice and a great deal of investment on the part of the teacher. While some teachers were not 100% convinced about the value of such an approach, many recognized that practice makes perfect. Participants felt that the program developers and facilitators did an excellent job in engaging them in the rediscovery process, which is replete with challenges, failure, and ultimately, success. As one teacher shared, the opportunity to grow with her students was invaluable. The methods she learned in the program had permitted her to present topics in a more engaging fashion, and she hopes that the result will be better uptake, understanding, and retention/recall by her students.

Overall, the course appeared to promote a heightened awareness of teaching science and technology, and the changes reported were as varied as the educators themselves. In general, those who possessed a strong science background stated that their teaching practices were not significantly changed by the course; however, those with less science and technology experience reported more dramatic changes. Some of the predominant reported changes in teacher practices are summarized below:

- Teachers placed more emphasis personally and pedagogically on the design process.
- Seeing the big picture and not being as captivated with specific curriculum expectations created opportunities for more professional risk taking and more emphasis on inquiry and design processes.
- A greater emphasis on the design element of the curriculum was fostered.
- Critical thinking has been promoted and encouraged—teachers seeing their practice in new ways. Teachers are more conscious of how they teach and why they teach the way they do: there was a movement away from a text-based approach and more focus on a student-centred approach.

What changes did project implementers see in teachers?

We interviewed the project implementers, including two project leaders from The Learning Partnership and all four project facilitators, to get their opinions on teacher changes. The Learning Partnership leaders were responsible for leading the design, management, and implementation of the project; the project facilitators were responsible for moderating the online discussions and leading breakout discussions in the face-to-face sessions for the same group of teachers throughout the project. None of the implementers actually visited participants' classrooms, so reports were based on talking to teachers either online or in person.

The implementers noted two changes in teacher practice over the duration of the project. First, there was a consensus that teachers shifted away from traditional blackboard and textbook teaching to more of an inquiry-based approach to science and technology lessons. This approach did not emerge without some trepidation, however. One implementer said of teachers:

> *The first couple of times they were sort of apprehensive, you know afraid of the students sort of taking over or misbehaving, and then I guess a revelation happened about how much the students enjoyed and then how much they were learning from the hands-on activities.*

However, in response to feedback from colleagues and facilitators, teachers began to develop confidence and expressed a willingness to re-work their lessons. It was suggested that for some participants, the science and technology program provided a review of inquiry teaching that had been learned at one point in their training but never applied. The program provided the framework to support the implementation of this approach. Although it was suggested that lack of equipment and resources constrained teachers in some schools, as the program evolved teachers found ways to do science and technology experiments using everyday materials, mitigating the problem.

The second change noted was a shift in teaching emphasis. Initially, teachers tended to focus on questions of content and expectations as though the curriculum was a list of skills teachers needed to check off as they taught them. As the program wore on, their talk shifted to discussion of the "big picture" in science and technology, and focused on topics such as higher order thinking skills and how they could be incorporated into their lessons.

At least two implementers suggested that teachers generally benefited from the program in direct proportion to the time and effort they put into it. Almost all of them cited examples of teachers who had benefited from the program:

- One teacher had her students undertake a Rube Goldberg machine project, in which they designed a complex machine to do a very simple task. And by doing that she was able to meet many of the expectations in the unit that she was teaching, and yet do it in a way that the students enjoyed.
- In the first module, a teacher did a unit on flight and had her students make paper airplanes. Both the teacher and students enjoyed the experience tremendously. The teacher found that she could meet many of the curriculum expectations through the activity, and not actually have to formally teach them—she was surprised that the students could learn the skills on their own.
- A teacher reported that her students did a "fabulous job" of linking the systems of the human body with graphic organizers that she just "threw out to them," and asked them to put together a coherent scheme to relate the systems of the body to each other. The teacher said that her students "came up with some incredibly creative classification systems that she wouldn't have thought of herself."
- One implementer described a teacher who "taught us all some stuff." The teacher assigned a budget to every experiment that the students had to do, and they had to be responsible for their financial resources. For example, she had students design a bridge to span a lake. She told students that the first thing that they had to do was to develop a budget (which reinforced math skills). Then they had to pay the architect's fee and buy the steel, which was represented by coffee sticks, and so on. If they made mistakes, they would lose money.

Finally, implementers were asked if they had seen evidence of teacher collaboration as a result of participation in the science and technology program. Consensus seemed to be that the program prompted some collaboration between teachers within same schools, and between teachers at different schools and school boards via e-mail, although none were aware of specific details.

What changes did principals/supervisors see in teachers?

In mid February, invitations were sent to 11 principals from participating schools along with five supervisors in the Toronto and Toronto Catholic District School Boards to participate in telephone interviews regarding the impact of the TeL project. These principals were responsible for the schools in which we carried out classroom observations. In total, nine principals were interviewed out of the eleven, one could not be reached and another declined to participate. Two of the five supervisors declined interviews because they felt that they did not know enough about the program.

Principals. Several principals mentioned that the program added to the teachers' repertoire of instructional strategies and provided new perspectives and opportunities for thinking about how to teach science and technology differently via an inquiry approach. Generally, principals thought it was too early to observe overall changes in the way teachers were conducting their classes. They did notice, however, specific instances where participating teachers had used activities and ideas they assumed were from the TeL Project:

- Increased use of lab facilities and equipment for hands-on activity. (5 responses)
- Increased use of computers and software integrated with science and technology activities. (2 responses)
- The project reinforced "creative" methods already in place. (2 responses)
- Research on the Internet for a robotics challenge activity. (1 response)

Principals also reported changes in co-curricular activities:

- Some improvements in the quality of student participation in other initiatives such as Science Fairs or Technology Challenges. (2 responses)
- Science Clubs, e.g., electric car club. (1 response)
- Using presentation software as part of science fair projects. (1 response)

Changes in collaboration were reported too:

- Increased collaboration with other teachers in the school. (4 responses)
- Sharing resources, lessons or ideas in grade meetings, "lunch and learn" sessions, or staff meetings. (4 responses)
- More informal, self-initiated sharing and collaboration. (2 responses)

Additionally, two principals reported positive feedback from student teachers in TeL participant classrooms.

Generally, principals reported that teachers who remained in the project appeared very satisfied with the experience. Most noted that although participating teachers already had favourable attitudes towards teaching science and technology, their attitudes and confidence were re-affirmed by the project.

- Favourable reports to the administration about the TeL program and science and technology. (4 responses)
- Excitement about student engagement in hands-on activities. (3 responses)
- The project, especially the collaborative aspects, has helped to build teacher(s) confidence. (3 responses)
- Participation in TeL helped the participant, a school lead teacher, to help and share information with other teachers in the school. (1 response)
- A teacher realized that so much more investigation could be done despite lack of science and technology resources. (1 response)

Board supervisors. Generally, the supervisors were very pleased with the program. They indicated that this project, which built on the previous TeL experience in mathematics, is paving the way for innovative approaches to professional development for their Boards.

Although supervisors were not in a position to observe changes in teacher practice in classrooms, through discussions with school administrators and participants at TeL events, they inferred that teachers found the overall program increased their confidence and comfort level in teaching science and technology, a subject in which most had very little recent background. The supervisors believed that after overcoming some early frustration with the chatroom set-up and concerns regarding the amount of time needed for effective online participation, teachers liked the combination of face-to-face and online activity. Finally, they felt that teachers either bought into, or had confirmed, their belief in the hands-on, experiential approach as a means to improve student learning, thinking skills, knowledge, and attitudes regarding science and technology.

What the research team observed about teachers

Even though we visited teachers in the Fall and returned in the Spring, direct comparisons between these two sessions would be fraught with difficulties due to observational methodology. Essentially our two "snapshots" were based on whatever teachers happened to be doing at the time of the visits. Teachers were told that they should continue teaching as they normally would and not to prepare any special lessons. We talked to teachers before the lesson started to see what material they intended to cover, and debriefed afterwards to find out how well they thought the lesson went. The findings in this sub-section focus on the Spring observation and report the practices teachers were engaged in at this time.

Lesson topics. We observed teachers teaching a wide variety of topics. A few illustrations of the topics/projects teachers covered during our visits are listed below:

- A design project which involved students building, analyzing, and testing race cars they created.
- In a split grade 5/6 class, the grade 5's were designing a contraption to bring people in wheelchairs from one level of an amusement park to another. The grade 6's were developing an amusement park ride that used two of the following three: a change in motion, a change in speed, or a change in direction.
- The continuation of a long-term project that incorporated learning objectives from two grade 8 science and technology strands: Structures and Mechanisms, and Matter and Materials. Students were designing, building, and testing a prototype hydraulic "crane" that had to meet certain requirements—grasp a pop can, lift it a specified distance, turn it through an arc of 120 degrees, extend the can, and place it on a platform of a specified height.
- Student experiments using simple materials to examine the effect of degree of a pendulum's swing arc and a pendulum's weight on the swing time of a pendulum.
- As part of a unit on the different types of motion (for grade 6's) and structures (for grade 7's), students assembled LEGO project that included gears, pulleys, screws, wheels, and levers to build small machines that incorporate different types of motion studied previously (linear, circulating, reciprocating, and oscillating).

The three-part lesson. The lesson pattern that teachers followed was fairly consistent across all of our observations. In some cases, we observed a new project being started and in others we came into an ongoing project. All teachers employed at least the opening and extended middle of the three-part lesson, but as illustrated below, the concluding part was either missing or fairly weak. Some examples of how teachers began their lessons follow below:

- Students were reminded of the expectations for their work during the period. The class reviewed safety procedures and co-operative group skills before they began work for the day. They also reviewed the concepts and words involved in the building of their cars (simple machines) with the use of a literacy strategy being employed across their curriculum.
- Definitions of various terms (e.g., angle of incidence, angle of reflection, normal) that would be needed in the activity were reviewed. The teacher went over procedures and talked about handling materials. Students were shown a ray box and given a demonstration on how it would be used for light experiments.
- The teacher started by eliciting prior knowledge of pendulum motion from a parallel experiment that had been done the previous day that examined the relationship between pendulum length and pendulum swing time.

After the introduction teachers typically had students work on hands-on projects in small groups. During this time, teachers circulated around the classroom to provide assistance or to answer questions. Below are five observations we made in different classrooms that are representative of what we saw:

- The subject matter chosen by the teacher was appropriate (i.e., *Reflections* is a topic in grade 8 science and technology), but students were not "investigating." They were following the "cookbook" approach of the textbook.
- Although the lesson was very procedural, it clearly (to the teacher) represented a big step forward. The teacher had gone to considerable trouble to obtain materials, in this case, three ray boxes and three mirrors.
- The teacher spent the entire time that students were experimenting wandering around observing, checking experimental reports, and coaching when students did not seem to be completing their forms properly or lacked understanding of concepts or procedures.
- The teacher circulated to observe during construction activities, prompting groups to focus on certain elements of construction when they were stumped, and later prompting for analysis of machine types where progress was observed to be deficient.
- 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 measures of the 90 and 45-degree angles she demonstrates.

These examples also illustrate some of the variations in the design and approach taken by teachers in lessons. The first two examples represent a very "traditional" approach to science and technology in that the teacher controls what students are to "discover." The latter three are examples of more open-ended lessons where students were given more freedom to experiment.

(One of the researchers, expert in the Ontario science and technology curriculum and expectations, visited a class of grade 8 students and observed that much of the students' project work was "informational" and typical of what grade 3 students produce.)

As initially mentioned above, when teachers concluded their lessons we observed little evidence of activities to synthesize or reinforce the learning that had just taken place. For example:

- The closing was held with 5 minutes remaining in the class. The teacher called for the attention of the class with a countdown and "all work stops now" announcement. She reviewed what students needed to accomplish in the clean-up portion of the lesson. Instructions were clear and succinct.
- The closing was held with 15 minutes remaining in the class. The teacher called for the classes attention with a count down and "1, 2, 3 eyes on me" announcement. She had students leave their work and come to a large open space in the classroom (a carpet on the floor). The class and teacher then reviewed what they needed to accomplish in the remaining time in the period. Five minutes before the end of the class the teacher had students begin clean-up and shelving of their work. There were no other closing activities in the class period.
- There was no real closing to the class. … According to the teacher, the students' experimental results will be taken up and discussed in the next class.

Questioning. During our observations of the lessons, we noted the questioning techniques teachers employed. In one case, we saw very effective questioning:

> 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 carryout tasks as they did. She also held impromptu brainstorming sessions involving the whole class during the course of the lesson.

However, most questioning was fairly superficial, as illustrated in these excerpts from our notes:

- There were no questions about the substance of the science and technology. The questions were all of the "Does it work?" type.
- There were no guiding questions for the project.
- The activity could be anything from the book, so the teacher was not asking particular questions about student understanding; most questions were of the "what did you decide to do?" type.
- The questions asked were mainly about why students had decided to do something particular, or how they thought their model would solve the problem.

Teacher subject knowledge. Generally teachers were reasonably comfortable with the subject matter—largely physics—during our observations, although they were more tentative than in the Fall when the topics were mainly about biology. We did observe one teacher who had numerous errors in their materials, but was not aware of this fact.

Discussion

We collected data from a variety of sources to answer the question about effects of the TeL science and technology program on teacher confidence and capability in creating an engaging learning environment. From these data, we can draw several overarching conclusions:

1. Teachers were either satisfied or very satisfied with the professional learning experience the project afforded, regardless of whether they had strong science and technology backgrounds or not. Experienced science and 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.
2. Teachers increased their confidence to experiment with different approaches to teaching science and technology 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. Added to this, was the confidence gained to deal effectively with the unpredicted as it arose in their classes and to venture into topics where they might not know all of the answers to questions students might ask.
3. Even though teachers reported that their subject matter knowledge increased, particularly in Life Systems, Earth and Space Systems, and Matter and Materials, teachers still needed assistance in learning curricular content, particularly in the Energy and Control strand.
4. Not all teachers were convinced of the desirability of introducing HOTS into their classes. Among the concerns expressed was the significant amount of time it takes to develop HOTS lessons and the ability of some students, particularly the low achievers, to handle HOTS questions.

Although teacher attitudes toward the program and its pedagogy were positive, we did not obtain convincing evidence on how much teacher practice actually changed. Teachers reported introducing new inquiry-based activities and more open-ended scientific exploration into their curriculum, but their interpretation of what inquiry means may not necessarily be that which the program developers' intended. We saw evidence of some inquiry learning occurring in classrooms, some very "traditional" teaching, and teachers making efforts to implement inquiry-based approaches, but by no means was inquiry learning widespread. Also missing was much evidence of teachers implementing the three-part lesson very effectively, particularly the third part of the model. Nevertheless, the fact that teachers developed more positive attitudes and increased confidence bodes well for teachers taking the next step and improving their approaches to teaching.

4. Findings on Student Impact

Evaluation Question 2: *What was the impact of the program on students as demonstrated by their classroom engagement and perceptions about science and technology?*

Although the TeL Project was directed at teachers, the expectation was that by introducing improved activities, resources, strategies, and ideas into the science and technology classroom, students would benefit. We examined this question through student survey responses, analysis of teachers' journals and the evaluation forum transcripts, principal and key informant interviews, and our own classroom observations. We begin by describing the students who were in the participating teachers' classrooms we surveyed.

Who were the students in the project?

Of the 551 students who completed the spring survey, 244 (44%) were from grade 6, 210 (38%) from grade 7, and 95 (18%) from grade 8 (two students omitted the question). A large majority of them reported receiving A and B grades for science and technology (74%), with the remainder reporting that they got C or D grades or were unsure of their grades. Eighty-two percent reported spending two hours or less on science and technology homework in a week; 14% spent from 3 to 5 hours; and 4% reported 5 hours or more. Three-quarters of these students aspire to attending university. Of the remaining students, as many reported expecting to go to as far as high school or community college as those who did not know how far they would go.

How did students' views about science and technology change?

We compared results between the Fall and Spring student surveys to see how student views changed. Of the 551 responses in the Spring, only 401 were usable for this analysis as the remaining 150 responses could not be matched to the Fall. This appears to be due to teacher errors in assigning survey IDs and/or having students who were not in the class in the Fall do surveys in the Spring so that they would not be excluded from the activity. As noted with the teacher survey, it is difficult to attribute directly to the Teacher eLearning program any change in student attitudes, as there was no comparison group. Caution must be used, therefore, in interpreting the results.

Overall, we found that five questions had statistically significant differences between the Fall and Spring responses. These are shown in Table 4.1 following.[4] For the sake of readability, non-significant responses are not presented in this section. A copy of the student post program survey with response frequencies for all questions is given in **Appendix B**.

[4] Because the sample size for the student survey is so much larger than the teacher survey, it is far easier for statistically significant differences to be found. Therefore, caution must be used when interpreting results as the statistically significant differences may be so small that they are not educationally meaningful.

Table 4.1 Survey responses about science and technology (N=401)

Quest. No.	Question	Fall Mean	Spring Mean	P
6d	My family thinks it is important for me to be good at sports. (Strongly agree=1 to Strongly disagree=4)	1.93	2.05	.040
7b	In my science and technology class, students often work from exercise sheets to practice what the teacher taught. (Strongly agree=1 to Strongly disagree=4)	1.89	2.03	.002
9d	Science and technology is my weakest subject. (Strongly agree=1 to Strongly disagree=4)	3.15	3.29	.009
13c	In our science and technology class we work from worksheets or textbooks on our own. (Almost always=1 to Never=4)	1.83	1.93	.025
13d	In our science and technology class we work on hands-on activities such as lab experiments. (Almost always=1 to Never=4)	2.55	2.40	.026

A notable finding was that significantly fewer students agreed in the Spring than in the Fall with the statement that their family thinks it is important to be good at sports (question 6d). This question was asked in conjunction with three other questions on family views: importance of doing well science and technology (6a), having time for fun (6b), and doing well in mathematics (6c). (See **Appendix B** for the latter three questions.) One might presume that the de-emphasis in sports and fun would translate into increased emphasis on science and technology and mathematics; however, no significant differences were found between Fall and Spring. Nevertheless, there was a trend toward increased emphasis on science and technology versus fun. However, the importance students placed on mathematics was nearly identical between Fall and Spring.

Questions 7b and 13c suggest significant changes in pedagogy between Fall and Spring, with less use of worksheets and individual seat work, respectively. As suggested by responses to question 13d, teachers appear to have significantly increased the amount of time spent on hands-on activities, such as lab experiments, to compensate for less time spent doing worksheets. This change corroborates teacher reports discussed in the previous section that more time was being spent on active learning.

The increase in hands-on activities (13d) may have led to a change in student perception with regard to their learning success in science and technology. Question 9d suggests that significantly fewer students viewed science and technology as their weakest subject in the Spring then had done in the Fall.

How teachers viewed student changes

We drew upon the evaluation forum and teacher journals to describe how teachers viewed changes in students' attitudes and learning in science and technology. They reported that, in general, improvements were noticed in both student confidence with, and a desire to learn, science and technology. Increased enthusiasm and greater interest in the subject was noted by several teachers:

> *I have witnessed or noticed that students are more engaged, they are more motivated. They seem to be really into the science, and some of them have chosen science as their favourite subject now whereas it wasn't before.*

Teachers observed that students were more willing to get involved with class experiments and report on their findings. Students also 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 behavioural comments from supply teachers using the science and technology day plans they left behind: they attribute 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 familiar with teamwork felt that students needed more time to develop these skills.

According to teachers, hands-on learning has opened the eyes of students to new experiences, enabling them to better make connections with what they learn in school to their own lives. Many teachers also noted that students were beginning to accept more ownership for learning. The role of the teacher had shifted from "sage on the stage" to a more facilitating one, which helped create an environment that encouraged students to learn on their own. Observed one teacher:

> *I'm not as important to their learning as I thought I was! I can actually let them "go" and they will learn certain things. I've got to create the environment, I've got to be there to do the controlling of it, but I can let them learn a lot on their own…*

What is abundantly clear from the evaluation forum transcripts is that the integration of hands-on experiences into the class, coupled with the design and inquiry processes, fuels a richer learning experience for students. Students are able to make connections to other learning and experiences in everyday life. Teachers are moving away from answering questions and are placing a greater emphasis on having students answer their own questions and each other's. One teacher reported:

> *The biggest impact on student learning that I find is through the design and inquiry process. Although I have been doing hands-on activities for many years it's only this year, after teaching the actual design and inquiry process, that the students - while building or performing different experiments - are really thinking about the impact of their decisions and going back to those processes. And so I guess you could say it's not only hands-on but it's minds-on.*

Teachers saw the inclusion of hands-on activities as beneficial to every kind of learner: students of any ability can be motivated and can enjoy what they are doing in the learning environment. Teachers expressed that students who struggle with learning or language (ESL or LD) are able to contribute meaningfully and that groups were able to build on each other's ideas when hands-on activities were employed in the science and technology classroom. Said one teacher:

> *All learners benefit as the inquiry approach coupled with hands on activities is driven by the mind of the child – it can go where ever it takes them – it is less restrictive on the basis of ability. I find even for the high achievers though it gives them that little bit of extra enrichment or stimulation that they are not going to get through [traditional] work.*

Another teacher mentioned a connection between improved student grades and her own professional growth, however, many felt that they had not had sufficient time to accurately gauge developments in their students. They did, however, state that their professional development had enabled them to better help their students grasp difficult concepts. With more time they hoped to see such development further enable students to make even more sense of their world through the use of science and technology skills and concepts.

What principals and implementers said about student changes

We asked principals about changes they observed in students whose teacher was participating in the TeL Project. Principals believed that student attitudes towards science and technology depended on both the teacher and the approach being used. Generally, it was noticed that when teachers used hands-on activities, students appeared to be more engaged and interested in lessons than when lessons were based on the textbook. Specifically, mention was made of the following:

- Students are more excited and motivated to participate in science and technology activities and classes than before. (9 responses)
- Student behaviour in science and technology classes is improved. (2 responses)
- There is increased participation in science and technology co-curricular activities (e.g., science fairs and technology challenges); some students stayed long hours after school. (2 responses)
- There is increased school awareness of science and technology (e.g., lunch time club and items in the daily school announcements). (1 response)
- A dip in student performance on tests was noted. (1 response)
- There is discernible change. (1 response)

None of the implementers were present in classrooms, so when asked about student change, they were somewhat reluctant to comment. Nevertheless, they cited several anecdotes given to them from teachers. One implementer talked of a teacher whose students went from dreading science class to really enjoying it, particularly when working in groups. Moreover, the teacher was surprised at how much students were able to achieve with this particular approach. Another implementer said teachers reported that the program, "*…definitely increased student motivation…[teachers] are talking about students' interest level increasing and desire to get involved, especially with the hands-on components*." Teachers mentioned that their students were coming in to class to work on science and technology projects before school, during lunchtime, and after school. A different implementer said, "*You don't often hear the negative stories, but I did hear a good number of positive ones where kids got engaged with different elements of different projects*." One teacher report the implementer heard about was students getting excited about building hydrometers; another was about children taking home experiments and testing foods in their refrigerators for acidity.

What the research team observed about students

Generally speaking, our observations were consistent with what teachers and principals reported: namely, that students were motivated and engaged by the approaches taken by the teachers. Below are some excerpts from our observation notes supporting this view:

- Students worked very well in their groups. They showed interest in the material, spent time reading the pages, and discussed ways they could make things fun for the little ones [i.e., they were making projects for students in lower grades].
- There were no class management problems. Students were on task and very focused on learning more about their topics (e.g., tension, stability, loads). They are an incredible group—possibly because this teacher had most of the students last year (when the teacher was also in the TeL Project) and has fostered a sense of community in the class.
- Students were extremely motivated and engaged in the task; they required little redirection. When problems or errors arose they were dealt with in a team-like fashion with solutions brainstormed in small groups and also as a class.
- Students were usually very absorbed in their experimental tasks. There was very little off-task talk observed, although there was a bit of playing around with the pendulum apparatus observed on occasion…. Students were generally very attentive when the teacher or other students were talking; no discipline issues emerged.

Unfortunately, there were some exceptions to these positive observations:

- Same comments as in the Fall: the teacher does not use good class management strategies. [The teacher] continually asks for quiet and attention but students often ignore this—they are a very chatty bunch. There were no obvious problems, but there was a sense that the students didn't think it was important to pay attention.
- Not much appeared to be different from the initial visit in the Fall. Student presentations of their projects were, to a student, disappointing. Evidence was sparse, reports were lengthy and very descriptive, suggesting more than anything, a process of "reading text for information" rather than experimentation and discovery. In only one student project were there concrete artifacts demonstrating an investigative approach to knowledge gathering.
- Student work that was shared through a large group presentation was of Level 2 quality at best. Little quality effort appeared to be put into these investigations.

These latter observations suggest that the increased engagement of students was by no means universal.

Discussion of findings on student changes

We found very good agreement across our various data sources about the impact of the project on students. The significant changes between Fall and Spring on the student survey were supported by comments from teachers and principals: namely, that overall students viewed science and technology as slightly more important; that teachers were relying less on worksheets; that there was more emphasis on hands-on activities; and that student confidence in their ability to succeed in the subject increased.

Teacher reports on how the program affected their students were largely borne out by principals and our own observations. In summary: students started to enjoy science and technology more than they had previously; they were more engaged in and motivated to learn by the inquiry-based approaches that teachers had begun to try; students took more ownership in their work; and better teamwork skills had begun to develop. The view that it was too early to see any increase in student achievement was also supported, to some extent, by our classroom observations. This is not a surprising as expectations that a professional development program of this limited scale could have a significant impact on student outcomes in just over half a year would be unrealistic.

5. Findings on Differential Effects

Evaluation Question 3: *Did some students benefit more from the program than others?*

The TeL Project drew upon teachers from high and low socio-economic status (SES) schools. One primary focus of this study was to see if learners in low SES schools derived more or less benefit from their teachers' participation in the program than those in high SES schools. The two main sources of data to address this question were the student survey and teacher observations. We analyzed the student survey responses by SES and examined the qualitative data to see if any other patterns emerged, such as gender differences or differences between special needs students and mainstream students.

Student survey responses in high and low SES schools

We examined survey responses of students in high and low socio-economic status (SES) schools to see if there were any significant differences between Fall and Spring. The SES of a school was determined by data provided by the school boards. For schools in the Toronto District School Board, we used the Board's Learning Opportunity Index. The index, which ranges from a low of 1 to a high of 472, takes into account information from the following variables: average and median income of families with school-aged children; parental education; proportion of lone-parent families; recent immigration; housing type (apartment, single detached housing); and student mobility. For the sake of our analysis, schools rated below 260 were classified as low SES, and those at or above 260 were classified as high SES. The Toronto Catholic District School Board does not have a formal system for classifying schools; therefore we relied upon expert opinion from school board staff as to whether a given school was considered low or high. Of the 401 usable student responses to the survey, 306 were from low SES schools and 95 were from high SES schools.

Significant differences from Fall to Spring were found on four questions. Questions 7c asked to what extent students agreed that they worked on science and technology projects often. As can be seen in Figure 5.1, in the Fall, students in low SES schools reported working on projects more often than students in high SES schools (a low mean indicates *more agreement* with the statement). By the Spring, the opposite occurred: namely, students in high SES schools worked more often on projects than students in low SES schools.

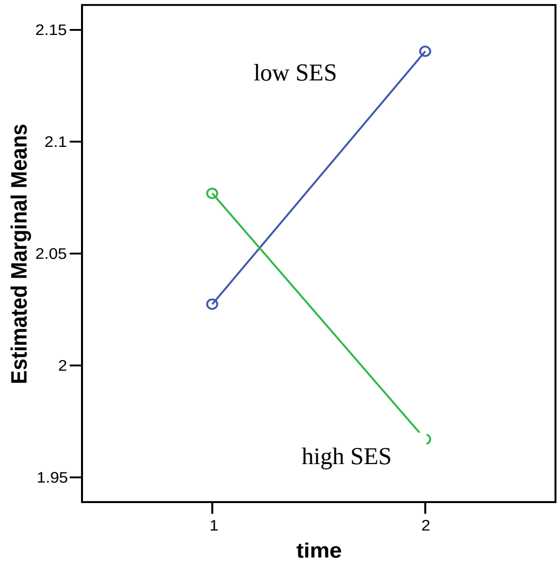

Figure 5.1 High and low SES student means in Fall (1) and Spring (2) on how often students work on projects

Question 11d asked students how important they felt science and technology was to "everyone's life." Again, we saw the same pattern emerge as shown in Figure 5.2. Students in low SES schools viewed science and technology as more important in the Fall than the Spring, while students in high SES schools viewed it less important in the Fall and more important in the Spring.

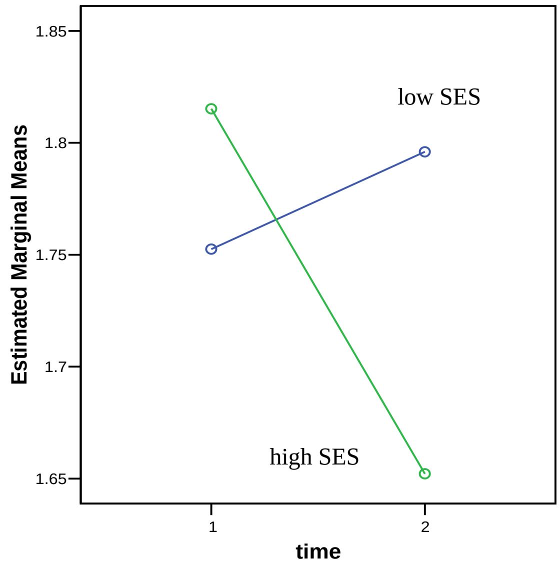

Figure 5.2 High and low SES student means in Fall (1) and Spring (2) on importance of science and technology in everyone's life

The third question exhibiting significant differences was Question 12a, which asked students how often teachers explained rules and definitions when introducing a new topic in science and technology. Figure 5.3 shows the response means for this question. The data revealed that rules and definitions were given more often in the Spring to students in high SES schools and less often to students in low SES schools (a low mean indicates that explanations occur *more often*).

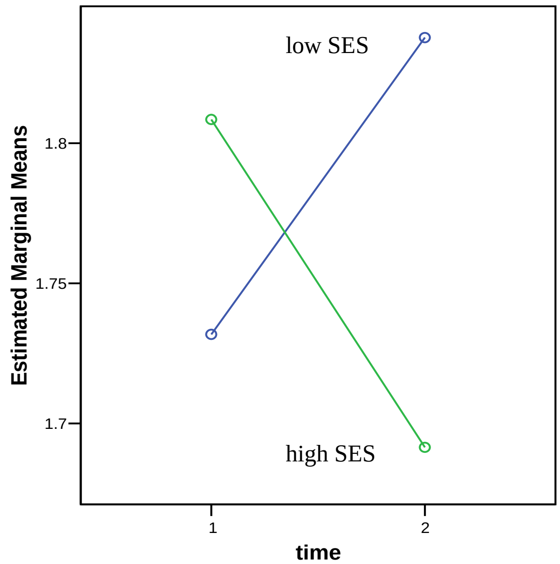

Figure 5.3 High and low SES student means in fall (1) and spring (2) on how often teachers explain rules and definitions at beginning of a new topic

The final significant result was obtained through question 12d, which deals with how often teachers, when introducing a new topic, ask students what they know about related topics. (A low mean indicates that it occurs *more often*.) The data shown in Figure 5.4 indicate that in the Spring teachers used this technique less often for students in high SES schools and more often for students in low SES schools.

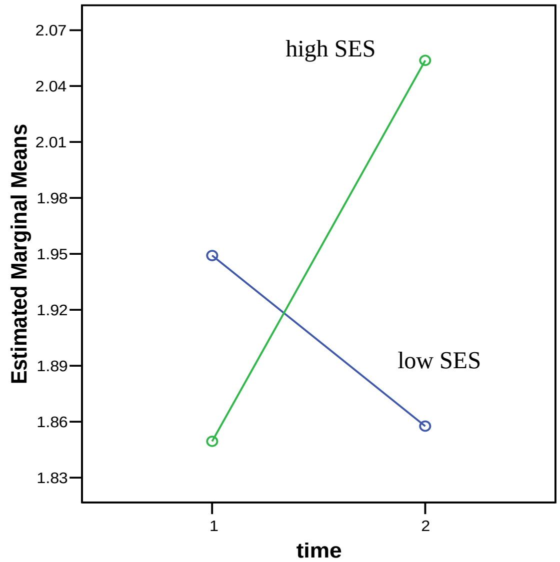

Figure 4.4 High and low SES student means in Fall (1) and Spring (2) on how often teachers ask students what they know about topics related of a new topic

Teacher observations on meeting diverse needs

Teachers were asked in the evaluation forum to describe what impact the teaching methods learned in the TeL Project had on the diverse needs of students. Comments centred on ESL and special needs students.

To begin with, they indicated that students with special needs, or those who are currently withdrawn for ESL support, are fully integrated into science and technology classrooms. As the majority of these students do not receive any additional support in the science classroom (other than individual attention from the classroom teacher), teachers identified the many challenges in modifying the curriculum, and creating meaningful activities that are at the language and ability level of individual students. What became clear was that many found that their increased knowledge of inquiry methods, problem-based learning, and design activities for science have helped to engage students with learning disabilities and to foster a desire to learn. Said one teacher:

> *I have found that my special ed students, the ones with learning disabilities and things like that, are getting up to par with everybody else just because of the motivation factor. They are really trying.*

Some common obstacles faced by teachers included providing hands-on learning opportunities due to a lack of available materials and/or manipulatives. The lack of resources was seen to limit what teachers felt they could accomplish with special needs and ESL learners.

> *The limitations and the obstacles that I came across, and one big one, is the fact that we are lacking materials for the hands-on in our classroom. The activities are great and what we've learned is fabulous, however, material wise we're lacking.*

Teachers frequently mentioned ESL students, whose proficiency level of the English language limited their ability to have a positive and meaningful experience in science and technology classes. Teachers felt that their involvement in TeL provided them with strategies to engage these students despite a language barrier.

> *I think the hands-on helps all the ESL students in the sense that they actually get to see what you are doing, so they can associate the vocabulary to what they actually see in front of you, or they can associate a concept with actually seeing it happen because they don't have that language background.*

Teachers made the point that hands-on, problem-based learning and inquiry/design necessitates a different form of assessment, one that can overcome the limitations of traditional pen to paper evaluation and the reading of textbooks.

Observations of others

Principals were the only other stakeholders who offered opinions on differential effects of the program. They stated, however, that they had not collected much information first hand that solidly supported statements regarding differential effects. However, through comments from students and teachers, several offered the following inferences. With regard to gender:

- For more mechanical activities, boys were more interested than girls. (1 response)
- The biology component appealed more to girls than boys. (1 response)
- Students, especially girls, now love going to science and technology and are taking a greater leadership role. (1 response)

With regard to student exceptionalities:

- The approach worked better than previous (more text-oriented) methods for MID (Mild Intellectual Delay) and LD (Learning Disabled) students; they were more willing to take risks and engage in these activities. (2 responses)
- The hands-on approach was much more motivational than the textbook approach for exceptional students in classrooms where they were integrated; they felt more confident and were more successful. (2 responses)
- No discernible difference noted for ESL students. (2 responses)
- ESL students benefit from decreased emphasis on text-based learning; dramatic improvement in socialization where hands-on approach is used in science and technology. (1 response)
- Regular students outperformed students identified as Gifted in inquiry learning, which evened out the playing field in an integrated class. (1 response)

Discussion of findings on differential effects

Our goal in this section was to discern whether some students benefited more from having teachers in the TeL science and technology program than others. The data suggest two categories of students who benefited differently from the program: students of different SES backgrounds and ESL/special education students.

On four survey questions response differences between Fall and Spring were found for students of high and low SES. To summarize in terms of students in low SES schools, we found that relative to students in high SES schools in the Spring they:

1. Worked less on projects.
2. Felt science and technology was less important to everyday life.
3. Were given rules and definitions less often.
4. Were asked more often to connect prior learning with what they knew about a new topic being introduced.

The first finding is surprising because there is no evidence in our other data to support that teachers in low SES schools conducted fewer projects than in the past. We can only speculate that the projects were of extended durations; hence students perceived that they were working less. But if that interpretation is accepted, what is left unexplained is the finding that students in high SES schools reported working more on projects. The second finding is somewhat discouraging for students in low SES schools. We can only speculate that students in low SES schools may have thought that the hands-on work that they enjoyed doing was not “authentic science and technology,” hence they valued it less than the traditional approach. Our third and fourth findings were positive with regard to students in low SES schools and consistent with the pedagogical approach advocated by the TeL science and technology program. There is no obvious reason why teachers of students in high SES schools would have been given rules and definitions more often and did not as frequently connect new learning with prior learning.

Our findings for ESL/special education students are positive and encouraging. Teachers and, to some extent principals, reported that these students were able to benefit more from hands-on learning and activities with concrete materials more than they would from traditional directed teaching. As a consequence, these students appeared to develop more positive attitudes towards science and technology and take more risks while learning. As some teachers pointed out, a challenge they face is to have sufficient, quality concrete learning materials and manipulatives available for inquiry learning.

There was some speculation on the part of principals that boys appeared to become more interested in science and technology due to hands-on learning, and that gifted students may not perform as well with this approach; however we do not have any corroborating evidence from teachers to support this.

6. Findings on Other Issues

Evaluation Question 4: *What other issues arose in the Teacher eLearning Program?*

All of the data gathered to address the previous three evaluation questions were analyzed to determine if there were any other outstanding issues that arose in the TeL science and technology program. We identified several of these.

Overall teacher satisfaction

On the teacher survey we asked participants to rate the extent to which the program met their expectations on a four-point scale ranging from "Fully met my expectations" to "Did not meet any of my expectations." Responses were nearly evenly split between "Fully met" and "To some extent met." No participants responded to the other two options. General impressions from the open-ended questions on the survey also suggested that teachers were very satisfied with the program experience. In their journals, participants wrote how grateful they were for the resources provided and for their treatment (e.g., hospitality and facilities) at the face-to-face sessions. That is not to say teachers did not raise any issues about the program. These are described next.

Teacher time issues

Teachers always face the challenge of time: there are never enough hours in a week to accomplish all of one's goals. Not surprisingly, most teacher concerns centred on time management issues. Both in the evaluation forum and the open-ended survey questions, many teachers cited that they felt they did not have enough time to complete all the weekly course work. Three reasons were given for this: sufficient productive release time, support from superiors, and over extension. As for release time, teachers who were required to take their release time at their schools found that they were unable to safeguard this time—they found that securing uninterrupted time to dedicate to the program was a challenge.

Second, many complained that their principals were not as supportive as they could be, nor were they as informed about the program, as they ought to have been. This led to teachers being called to take over classes and responsibilities within their schools during release time. Teachers, who chose to do their course work at home, hoping to avoid these pitfalls, also faced challenges. Despite the high-speed access bonus provided by the program, teachers found that they did not enjoy their at home work experience due to feelings of isolation, frustration with lack of technical mastery, and time crunches due to family demands. Some teachers reported not taking all of the release time available to them because they felt guilty about being absent from class so often and preparing for a substitute teacher seemed more work then it was worth.

The third reason for the lack of teacher time appears to be that many of the teachers nominated by principals to participate in the program had numerous professional commitments competing for their time and their attention. One teacher we talked to, for example, was involved in Ministry workshops, Physical Education workshops, as well as the workshops associated with the Professional Learning Network (PLN) in addition to the TeL Project.

Face-to-face sessions

There was a general feeling that the face-to-face component was extremely valuable, and some teachers wanted more of this. Face-to-face sessions provided opportunities for teachers to connect with other teachers at the same grade level, to share ideas, and to grow from the expertise of the facilitators and fellow teachers. Participants valued the opportunities to come together and celebrate their best practices, experiences, challenges, and lesson/unit plans. Teachers also spoke of how this aspect of the program helped eliminate the feelings of isolation of those who were the only teachers of a particular grade level at a school (and potentially also the only staff member involved in the program).

Suggestions that were made by teachers to enhance the face-to-face experiences included the following:

- Make the content of the face-to-face sessions more sharply focused on useable science and technology activities for the classroom that meet curriculum requirements and spend less time on theoretical presentations. More packaged curriculum materials that could be taken back to their classrooms were also desired.
- Do not "cram" as much material into the sessions.
- Teachers desired time to meet with the program developers one-on-one during the face-to-face sessions, and wondered about the possibility of an "Ask the Expert" session.
- Create groupings by grade levels at face-to-face sessions, and also groupings for split grade teachers to facilitate the sharing of ideas, and the development of units, projects, and lessons to meet the needs of both the curriculum and the goals of the program.

Online component

Teachers had strong opinions about both the asynchronous discussion and synchronous chat components of the course. The following is a brief summary of their comments and suggestions for improvements:

- Online discussions need to be improved in terms of participation (both quality of interactions and number of participants) in order for teachers to benefit from them. Allowing participants to communicate with any of the facilitators (and not just their group's designated facilitator) was suggested as a remedy to this concern.
- Asynchronous postings were made only on a weekly basis in relation to the articles and other assignments for the course. However, the feedback received on postings (other than the teacher journal postings) was non-existent. While teachers initially had intentions of reading postings and responding to them, they stated that they did not have the time to accomplish this goal. As a result, the asynchronous postings were generally not viewed as a useful experience. Teachers proposed better organization for the topics of postings (e.g., have teachers post by grade level and by strands) and also the possibility of having bi-weekly postings (post one week and comment on others postings as your assignment for the following week). By organizing a response to other's views, a dialogue could be successfully moderated and would hopefully fuel greater discussion and participation.
- The journal entries met with generally positive reviews—teachers were quite happy with the degree to which facilitators responded to their journals and concerns. While some teachers admitted to not "being writers," they welcomed the chance to engage in reflection. Some teachers who participated in the pilot project found that the reflection topics were too repetitive, and strongly recommended that perhaps two or three topics be

given for reflections, thereby permitting teachers some choice in what they wished to reflect and write about.

- Teachers best enjoyed the assignments that permitted them to implement new ideas in their classrooms as opposed to just reading and writing a response; the practical value of the former was viewed as an opportunity to implement change and also to work on something relevant, grade specific, and pertinent to the lived classroom experience.
- High praise was received for the “Webliography” and the websites that were recommended for teachers. (At present this is an open space where anyone can post something to share; however, it could be expanded further in an assignment by asking teachers to add to the Webliography). It was also recommended that this be organized according to grade and strand.

Facilitators, for their part, found the experience of working with the program to be professionally rewarding and the workload reasonable. They valued the regular conference calls with The Learning Partnership staff and the assistance they received in preparing for their role. (The addition of these calls was a significant improvement over last year’s mathematics modules.) One suggestion for improvement was for facilitators to get together to discuss actual journals, without participants’ names, and to compare how each would comment on them. The use of exemplary comments from previous modules would be helpful in this exercise as well.

As would be expected, there was a decrease in the number of postings from Module A to Module B because the first module contained six journaling assignments, while the second module had only four. However, the percentage of participants posting two or more journal entries across all sections dropped from 76% in Module A to 57% in Module B. (Many teachers posted only one entry in the second module; had their participation been counted the participation rate in the second module would have more closely matched the first module.) We noted a strong positive correlation between the number of teacher journal postings and the number of facilitator responses, except for one anomaly. One facilitator did not do any postings at all in Module B, yet the teachers continued to make postings.

Additional comments from principals

Generally, principals thought the program was well worth the time and effort required of them and their teachers. Not one had an overall negative evaluation of the program. They had few, if any, problems or difficulties with the program. Compared with other such programs, they found this one relatively problem free and a valuable use of release time. Several issues of interest raised by principals are as follows:

- **Supply teachers**. They became a problem for principals to deal with only at times when demands increased due to other factors (e.g., increased sickness in the winter, date changes of other activities). In one instance, the amount of time away from the teacher’s core class led to increased student behavioural problems. Another principal said that because it can be difficult to get supply teachers with strength in science and technology, the science and technology program in rotary classes suffered when the teacher was released for TeL. Lastly, one principal suggested that the maximum number of days that teachers should be out of the classroom for the program should be no more than five or six.

- **Competition from other PD/school programs**. One principal said that Board activities in science and technology or mathematics required attendance of one or more teachers participating in TeL so that the teacher missed too much class time. In another case, TeL conflicted with other school priorities (e.g., literacy and social studies).
- **Parental comments**. Contrary to last year's mathematics program, principals reported no complaints from parents about teacher absence. Indeed, three reported that parents were supportive of the program. To elicit parental support, one principal mentioned sending a letter to parents at the outset of the program outlining the benefits and answering questions before they were asked.
- **Long-term benefits**. Half of the principals said that they felt privileged that their school was a part of the project, and would like to see it continued in science and technology or expanded to include more teachers. They felt that the project, if implemented over time, could develop the skills and knowledge of teachers to compensate for lack of specialist science and technology teachers in middle schools. One other principal expressed the hope that this project will spur the Board to make science and technology a curriculum focus (along with literacy and mathematics).

Discussion

The findings in this section reiterate that teachers and principals viewed the TeL science and technology program positively. The fact that there were no major issues reflects the skill of the program organizers in benefiting from the experience of the mathematics program the previous year. Improvements in scheduling the sessions, reducing the number of modules from two to three, and training of the facilitators are three examples that illustrate this point.

Nevertheless, three outstanding issues deserve closer attention when planning future sessions: teacher time, online sessions, and face-to-face sessions. As for teacher time, little can be done in terms of reducing program workload if it is to remain a substantive, professional learning experience. One solution may be for program planners to work more closely with principals to see what can be done to ease some of the pressures placed on teachers while they are participating in the program. This might include selecting teachers who are not participating in other professional development activities or selecting only those who have no other leadership positions in the school. Another option may be to encourage principals to better protect the release time of teachers, so that they are able to take full advantage of time available to them. What is not recommended is to increase the amount of release time because the current amount is as great as what is feasible. Ultimately, there may be no single program planning strategy that will work. Perhaps the only way to reduce teacher workload is for teachers to discuss the matter individually with their principals to see what can be done after principals have spoken to the program planners. This would require advanced planning and consultation with principals in June so that any arrangements can be implemented in September.

There is still room for improvement in the online sessions, particularly the structuring of the sessions themselves. Organizers need to look for strategies to improve teacher engagement and develop a stronger sense of community. Participants view the current model of simply posting answers to a weekly question largely as 'busy' work. Activities that might be incorporated into the online sessions include organizing debates, having teachers analyze previous weeks' postings for changes in views and practices, and having teachers work in teams to execute online projects. Facilitators will need to be trained to implement these activities fully.

The face-to-face sessions also require fine tuning. There is a fundamental tension organizers face: the need to "deliver" content and ideas to participants versus providing teachers with the opportunity to meet in various groupings (by grade or by moderator group), share, and discuss. One possible solution might be in lengthening the day. The 9:00 am to 3:30 pm school day should not necessarily be a constraint for organizers. Since there are so few face-to-face days, lengthening the time (e.g., by an hour or more a day) would allow for more flexibility and increase the chances of making the face-to-face day a more valuable experience. Teachers would need to be made aware of this before signing up for the program in September.

7. Findings on Sustainability and Transferability

Evaluation Question 5: *How can the project be sustained beyond its formal end and transferred to other settings?*

Sustaining and scaling up educational innovations, no matter how successful they may be, is one of the most challenging issues facing educators, particularly after external funding is withdrawn (Datnow, Hubbard, & Mehan, 2002; Elmore, 1996; Fullan, 2005). One of the TeL Project objectives was to create a professional development model that could be transferable to other settings. We asked the three key stakeholder groups in the program—principals, superintendents/supervisors, and the implementers—for their perspectives on this issue.

Principals' perspectives

Principals were asked if they had any plans in place to make particular use of the teachers who had participated in the project, such as having them give presentations to staff or mentor other teachers. Principals responded that it was too early in the year to have developed any definite plans. They did, however, outline several ideas they planned to discuss with their TeL participants:

- Allocate time at staff meetings for presentations and sharing of the results of the project. (5 responses)
- Encourage discussion and sharing of ideas from TeL at grade team meetings, "lunch and learn" sessions, and visits between classrooms. (4 responses)
- Build and highlight opportunities for learning science and technology from the TeL experience into next year's school action plan. (2 responses)
- Develop a proposal with other middle schools to reopen closed design and technology facilities for use in the science and technology program. (2 responses)
- Have TeL participants team up with other teachers and act as mentors. (1 response)
- Coordinate an approach for science and technology across grades 6, 7, and 8 e.g., implement the Science Fair more seamlessly across grades 6, 7, and 8. (1 response)
- Improve computer resources for science and technology next year. (1 response)
- Have TeL participants take the lead next year in integrating design and technology with science (curriculum and use of special facilities). (1 response)

This was encouraging as we felt that principals had begun thinking about how to best utilise the teacher expertise gained in the program. However, the extent to which this actually happens is beyond the scope of this study.

Supervisors' perspectives

While recognizing that significant change in teacher practice requires several years, supervisors outlined the following issues related to the sustainability of the TeL Project:

- **Administrative ease**: The program was well designed and relatively easy to administer both at the school and Board level. (There were no complaints or issues to deal with during implementation.)

- **Cost**: The program is fairly expensive, mainly due to release time costs. It may be possible to increase the proportion of online interaction and reduce face-to-face time, while recognizing that teachers need release time to reflect on and change practice.
- **Related models**: It might be possible to develop other innovative models: for example, transform the program into an Additional Qualification (AQ) course (the current 75 hours falls short of the 125 hour minimum for accredited AQ courses). Another idea was to adapt the program to become entirely online.
- **Learning community**: The participants have become a viable learning community and could become a very valuable leadership group in terms of supporting future science and technology professional development. However, to sustain the community the boards would need to arrange for ongoing facilitation and occasional face-to-face meetings.
- **Adaptability to other school subjects**: The TeL program in science and technology was successfully adapted from the previous program in mathematics. Superintendents felt that the approach could be adapted to other subject areas as well.
- **In-service overload**: Several administrators expressed concerns regarding in-service overload. Boards, schools, and the Ministry need to plan together to coordinate priorities and schedule activities to minimize this overload.

Implementers' perspectives

The implementers at The Learning Partnership realize that the TeL Project is successful as a pedagogical model, but not viable economically to be sustained in school boards in its current form. Since for boards the most significant costs of the blended learning approach is teacher release time, the implementers have begun to explore other delivery models. A possible model under discussion stems from one of the recommendations in last year's mathematics evaluation report. It involves an intensive summer institute just before schools open in September, followed by online sessions during Fall/Winter. At this point, no concrete plans have been developed to implement this model.

This spring another model was tried with support from TeL funds and the same two school boards. The model was based on the current science and technology program, with four significant differences. First, the program lasted only five weeks: it began and ended with face-to-face sessions and had online work in between. Second, the science and technology content was selected from the most salient content of modules A and B. Third, teachers participated and interacted online only with other teachers from their boards and the interaction was facilitated by a board staff person. And fourth, each board used their standard e-learning platforms: Blackboard for the Toronto Catholic District School Board and FirstClass for the Toronto District School Board. The aim of the program, known as Science and Technology Module C, was to demonstrate how well the content from eCollege learning management system used in TeL could be transferred to other platforms and how effective a shorter term blended learning experience could be.

Discussion

What is now clear is that the blended learning model resonates well with boards as an effective professional development approach. The cost of release time for teachers is the main stumbling block for boards, preventing further adoption of this model. Therefore, more cost-effective approaches need to be examined carefully, such as the summer institute model or the Module C approach. In doing so, care must be taken to make the reduced amount of time spent in face-to-face sessions even more effective (see previous discussion of this topic). Also, caution must be exercised with regard to the overall length of the program: research has shown that one major element of effective professional development is that it lasts for an extended period of time to provide teachers with an opportunity to grow (Hiebert, Gallimore, & Stigler, 2002).

Another related issue raised by our findings in this section is the need for schools to make better use of the skills learned by participants. Designing ways for TeL teachers to share their newfound expertise is essential for effective teaching of science and technology in the schools. One can only be disappointed with the apparent lack of planning in this regard. The ideas suggested by principals were excellent, but we had hoped that more concrete plans would already be in place. In future offerings of the program this type of planning needs to be emphasized to principals, so that opportunities for teachers to share their expertise with colleagues is not lost.

8. Summary and Recommendations

The data that we collected and analyzed for this report clearly indicate that the TeL science and technology program was successfully implemented. With regard to teacher changes, we found that teachers: viewed the program as a valuable professional learning experience; gained confidence to experiment with hands-on activity based learning; used more higher level questioning; tried out new kinds of teaching materials; provided students with greater autonomy for designing projects; grouped students more in mixed ability teams; and increased their subject matter knowledge. Students, too, appeared to have benefited: they became more engaged and motivated to learn science and technology; their views on the importance of the subject became slightly more positive overall; and they took more ownership of their work. Several distinctions were found between different types of students from beginning to end of the program. Of particular interest were the changes in attitude toward science and technology between different SES schools: students from low SES schools viewed science and technology as less important to everyday life by the end of the program, while students in high SES schools viewed it as more important. TeL program activities also appeared to be beneficial for ESL and special education students who became more engaged than they normally would have been in the subject.

Some aspects of the program require further attention. Despite responding to recommendations of the mathematics report that the program be shortened and rescheduled to avoid traditionally busy times, teacher workload continues to be an issue. Both the online and face-to-face components require additional refinement. The design of the online component needs to be examined for ways to better facilitate teacher engagement and develop a stronger sense of community among teachers. Teachers perceive the face-to-face sessions as attempts to introduce a considerable amount of content, at the expense of teacher interaction, where valuable teaching ideas could be shared. Although the blended learning model employed in this project is successful, concern was raised about the cost of sustaining the current version due to the high cost of teacher release time.

Keeping the above finding in mind, we offer the suggestions below to help improve it, or a variation of it, for the next TeL program offering.

Recommendation 1. *Ensure that the course expectations are clearly communicated to principals*. After two years of experience with the program we have seen that the program is demanding above and beyond the release time provided. Teachers and principals need to understand and address this issue before September, preferably in June. One suggestion would be to lighten extra curricular loads on teachers or selecting teachers who are not overly involved in other professional activities. Participants need to be made aware of the technical requirements for participation as well.

Recommendation 2. *Review the structure of the online sessions in order to develop a greater sense of community among teachers and a stronger focus on student work.* Research has shown that the most effective professional learning occurs when teachers can share with each other their standards for student performance and how their teaching methods produce the learning they find in their students' work (Supovitz & Christman, 2003). Teachers need opportunities to share, critique, and analyze their teaching with their peers. The online environment should facilitate these kinds of conversations. Therefore, we recommend that the developers review the design of the current online curriculum with a view to building a greater sense of community among teachers and focusing more on instruction.

Recommendation 3. *Enhance the training of facilitators.* A major step forward was taken with the science and technology program by holding regular meetings with facilitators to discuss problems and issues. We believe that their skills can be further enhanced by providing them with an opportunity to view and critique exemplars of facilitator responses to online postings.

Recommendation 4. *Consider extending the length of the day for face-to-face sessions.* Teachers indicated that they placed much value on these sessions, but the time constraint of having to fit all activities into a normal school day is problematic. We believe it is not unreasonable to extend the day by at least an hour to allow for large group sessions and small group sharing. Teachers would need to be made aware of this, of course, before signing up for the program.

Recommendation 5. *Consider altering the organization of the face-to-face sessions.* We recommend that less time during the face-to-face session be devoted to whole group activities, particularly theoretical discussions or presentations. Readings could be assigned to teachers ahead of the session so not as much time would be needed for this informational component of the program. This would allow for more time to be devoted to small, grade-sorted discussion groups where teachers work on curriculum projects or activities based on the concepts that they would have read about.

Recommendation 6. *Provide suggestions to principals on how to make better use of teachers who participate in the program.* The skills developed during the program are invaluable to instructional improvement in schools. We were disappointed to learn from principals that few were using the expertise of their teachers who participated in the program. It is suggested that principals be provided with ideas on how to plan for and take advantage of their teachers' newfound expertise. At a minimum, principals should be urged to have their participating teachers share with colleagues what they have learned, ideally these teachers would be given a leadership role in developing science and technology instruction.

Recommendation 7. *Engage program developers in a discussion about how the differential student effects of the program can be addressed.* As summarized above, our findings witnessed a drop off in attitudes about the value of science and technology with students in low SES schools. This is a disturbing trend for this group of students. One explanation could be that students in low SES schools see science and technology as a series of play activities (e.g., making a paper airplane), rather than a serious academic subject. Program developers need to consider this issue and devise ways of addressing it through program curriculum. Likewise, they should try to make sure teachers can capitalize on the apparent boost that ESL and special education students get from inquiry-based learning.

Recommendation 8. *Encourage boards to support a special electronic community for science and technology teachers*. Teacher professional development is an ongoing process and communities of practice can be an effective way to support professional learning. Therefore, we believe that the fledgling learning community that was started with the TeL Project should not be allowed to wither away. We urge that each board set up an electronic community for their "graduates" and other science and technology teachers who wish to join. Volunteers could be sought from graduates to serve as facilitators.

Recommendation 9. *Continue to encourage boards to plan for and adopt the summer institute model for the future professional development programs.* The experience and expertise engendered in the boards by this two-year blended learning experiment should not be lost. Last year we recommended implementing a more cost-effective model consisting of a late summer face-to-face institute followed by fall/winter online sessions. We continue to believe that this model has merit for boards and strongly recommend its adoption be considered.

9. Epilogue

As described at the beginning of this report, the TeL Project was a two-year undertaking with the first year focused on mathematics and the second on science and technology. To conclude this report, we provide a comparison between the two programs of our findings on teachers and students as well as of our findings on the program's differential effects. These comparisons are presented in the three tables below. Listed on the left of each table are key factors about teachers or students. To the right of each factor is a verbatim quotation taken from this report and the mathematics report that epitomizes our findings.

Table 9.1 Comparison of key quotations about teachers taken from the science and technology and mathematics reports

FACTOR	Science and technology	Mathematics
Satisfaction with Program	▪ Teachers were very satisfied with the professional learning experience the project afforded, regardless of whether they had strong science and technology backgrounds or not.	▪ Teachers overwhelmingly stated that their involvement in the e-learning program had made their own math programs more fun, hands-on, co-operative, and empowering for students.
Confidence	▪ Teacher confidence increased to experiment with different teaching approaches to science and technology 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.	▪ [This] confidence has made teachers more willing to experiment with new ideas, activities, and approaches in their classrooms. Even those who were already quite confident about their mathematics teaching abilities at the beginning of the program for the most part appeared to have benefited by trying new ways of having students solve problems and by thinking more broadly about the teaching of mathematics.
Online Environment	▪ Asynchronous postings were made only on a weekly basis in relation to the articles and other assignments for the course. However, the feedback received on postings (other than the teacher journals) was non-existent. While teachers initially had intentions of reading postings and responding to them, they stated that they did not have the time to accomplish this goal. As a result, the asynchronous postings were generally not viewed as a useful experience.	▪ Teachers had mixed reactions to the online learning experience, with some enjoying it and participating regularly, and others participating erratically or entirely dropping out from the online component.

Face-to-Face Sessions	▪ There was a general feeling that the face-to-face component, with its opportunities for in-depth sharing and exchange of ideas, were extremely valuable, and some teachers wanted more of this. These 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	▪ The presentation of math games during the last face-to-face session was seen as a highlight. Teachers articulated that they want to have more opportunities in which they could share best practices during face-to-face sessions. They saw this as integral to community development.
Pedagogy	▪ Not all teachers were convinced of the desirability of introducing higher order thinking skills (HOTS) into their classes. ▪ Teachers reported introducing new inquiry-based activities and more open-ended scientific exploration into their curriculum, but their interpretation of what inquiry means may not necessarily be that which the program developers' intended. ▪ Another predominant theme we found was teachers reporting a move away from conventional modes of risk-aversive directed teaching to a greater willingness to take chances, explore new options, and give students more leeway to explore and learn from failures.	▪ The idea of the three-part lesson seems to have taken hold, despite not all teachers having implemented it fully. Additionally, teachers are now favouring more open-ended assignments and activity-based learning using manipulatives, possibly are more skilled in questioning, and are relating mathematics more to everyday life. ▪ Teachers' ideas about how students learn appear to have undergone a transformation as a result of the program. They believe that students can learn in a more open-ended way than they had previously thought and that leaving students with puzzling problems is acceptable.
Subject Knowledge	▪ Teachers responded that they better prepared to teach Life Systems, Earth and Space Systems, and Matter and Materials at the end of the TeL program. The fourth area where there were no significant pre-post differences was the strand of Energy and Control.	▪ Teachers were asked how well prepared they were to teach eleven different areas of the mathematics curriculum. Most felt they were "very well prepared" to teach decimals, percentages, and fractions (73%). They felt they were not very well prepared for most aspects of geometry: definitions and properties (52%); symmetry, transformations, congruence, and similarity (52%); and coordinate geometry (51%).
Computers/ Materials	▪ A common challenge faced by teachers included the provision of hands-on learning opportunities due to a lack of available materials and/or manipulatives.	▪ A very positive reception was given to activities in Module B; the use of manipulatives and Geometer's Sketchpad were

	▪ [However] as the program evolved, teachers got ideas for doing science and technology experiments with everyday materials, which helped mitigate the problem.	highlights. Teachers reported greater confidence, and increased enthusiasm towards math with the use of Geometer's Sketchpad.

Table 9.2 Comparison of key quotations about students taken from the science and technology and mathematics reports

FACTOR	Science and technology	Mathematics
Importance of Subject	▪ One might presume that the de-emphasis in sports and fun [on the student survey] would translate into increased emphasis on science and technology and on math. However, no significant differences were found on these items between Fall and Spring. Nevertheless, there was a trend toward increased importance of science and technology and decrease in importance of fun.	▪ Students did not seem to value mathematics as much in the Spring as in the Fall as fewer agreed with statements that mathematics was important in their lives and that it was important to do well in mathematics to please themselves. Also disheartening was that more students agreed in the Spring than the Fall with a statement that mathematics is boring. The one hopeful sign is that by the Spring, more believed it was important to do well in mathematics than they had in the Fall.
Motivation/ Engagement	▪ Students started to enjoy science and technology more than before, they were more engaged in, and motivated to learn, by the inquiry-based approaches that teachers began experimenting with…they took more ownership in their work.	▪ Teachers and principals together reported that students enjoyed the mathematics activities teachers introduced from the course, and that students found them very engaging. They both saw signs of improvements in students' self esteem, attitudes, motivation, and better on-task behaviour as a result of project activities… however our classroom observations were less sanguine.
Behaviour	▪ Others have noticed fewer behavioural comments from supply teachers in the science day plans they leave behind: they attribute the changes to the fact that students are more engaged and directed in their learning.	▪ All but one principal reported that students who had often entered the mathematics classroom with a negative attitude—which often lead to misbehaviour and underachievement—were turned around as a result of the project.
Collaboration/ Teamwork	▪ There were mixed reports about students developing teamwork skills. Most teachers said that student collaborative skills	▪ Teachers felt that all learners demonstrated greater collaborative skills, higher order thinking skills and enhanced problem-solving skills.

	improved. They observed that students are also better at helping each other, especially on specific jobs that are related to a given task. However, teachers whose students were not familiar with teamwork, felt that students need more time to develop these skills	
Subject Knowledge	▪ Teacher views that it was premature to see any increase in achievement was also supported, to some extent, by our classroom observations.	▪ Most principals indicated that they had little hard evidence to "prove" that the project had affected student achievement…[however] three principals referred to improved EQAO scores for grade 6 students this year, and one attributed this to the teacher's use of new approaches from the program, which make children more interested in mathematics.

Table 9.3 Comparison of key quotations about differential effects taken from the science and technology and mathematics reports

Factor	Science and Technology	Mathematics
Student SES	▪ [By program's end] students in low SES schools believed that science and technology was less important [than in the Fall]. ▪ Students in high SES schools viewed science and technology as more important [in the Spring than had in the Fall]. We can speculate that students in low SES schools may have viewed science and technology as more fun and engaging, therefore not to be taken as seriously as other more traditional academic subjects.	▪ Surprising was the substantial reversal in student opinion about the importance of doing well in mathematics between high and low SES students from Fall to Spring. The attitudes of students in low SES schools actually increased over that period [while high SES decreased].
ESL/Special Education	▪ Teachers and, to some extent principals, reported that [ESL and special education] students were able to benefit more from hands-on learning and activities with concrete materials more than they would from traditional directed teaching. As a consequence, these students appeared to develop more positive attitudes towards science and technology and take more risks in learning.	▪ Teachers seemed to agree that special education students, students with exceptionalities, at-risk students, and ESL students seemed to have greater confidence and made an effort in math class when program activities were presented.
Gender	▪ There was some speculation on the part of principals that boys appeared to become more interested in science and technology due to hands-on learning, and that gifted students may not perform as well with this approach, however we do not have any corroborating evidence from teachers to support this.	▪ The only other differential effect observed by teachers was that boys seemed more engaged than usual with hands-on mathematics activities.

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Appendix A & B: Responses to Post-program Surveys