WORKSHOP TO CLASSROOM: HOW EFFECTIVELY NEW TEACHER SKILLS ENTER CLASSROOM PRACTICE

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Abstract

This paper explores the effectiveness of a model of the Pan-Canadian Science Institute in providing teachers with new hand-held technology skills, and explores the process of actually implementing these new skills into classroom practice. Teachers participated in an intensive, five-day professional development in-service institute where they worked collaboratively to learn and practice a wide range of uses of graphing calculators and linked data-gathering devices, and discussed and shared views on effective pedagogy with this technology. Pre- and post-workshop surveys provided data to assess the change in teacher skill with, and attitude towards, the use of this technology. Follow-up activity, including frequent and regular encouragement and technical support throughout the implementation period, helped teachers to evaluate and improve the efficacy of their efforts to implement this technology in the classroom and to determine what impact this may have on their students in high school science. Through teacher reflective practices, survey data from participating teachers and students, classroom observation, and interviews with teachers and a sample of students, suggestions to improve the effectiveness of the Pan-Canadian Science Institute, follow-up activity, and implementation process have been determined.

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Introduction

Professional development activity is often a show-and-tell process, or a do-and-hope-to-use activity. How much of the information and skill that teachers gain in a professional development workshop actually makes it from the workshop setting to the school and into the classroom? And how much impact does this have on teacher practice and students? The focus of this project was to provide a significant professional development experience—the Pan-Canadian Science Institute—to a group of high school science teachers, and then follow-up to investigate how new skills were implemented into classroom practice and what impact this had on students.

Background

Over the last decade, much work has been done to try to coordinate curricula across different provinces in Canada. In 1997, the Ministries of Education across most of western Canada approved the development of common high school mathematics textbooks aligned with the mathematics framework of The Western Canadian Protocol. In 1995, the Council of Ministers of Education, Canada (CMEC) adopted the Pan-Canadian Protocol for Collaboration on School Curriculum. The first area for collaboration was the Pan-Canadian Science Project. This collaboration resulted in the K to 12 *Common Framework of Science Learning Outcomes* (CMEC, 1997). The use of technology, as a learning-aid and as a tool integrated into classroom practice, strongly supports many components of these new curricular frameworks. For example, the *Common Framework of Science Learning Outcomes* states as general learning outcomes that, by the end of grade 12, students are expected to "conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information" (CMEC, 1997, outcome 213), and "analyse data and apply mathematical and conceptual models to develop and assess possible explanations" (CMEC, 1997, outcome 214). The Pan-Canadian Science Project also promotes changes in student attitude related to technology such as the encouragement of students to "value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not" (CMEC, 1997, outcome 436).

The use of hand-held, portable technology also supports the *National Science Education Standards* (National Research Council (NRC), 1996). Teaching Standard D states,

> teachers make the available science tools, materials, media, and technological resources accessible to students. Effective science teaching depends on the availability and organization of materials, equipment, media, and technology. An effective science learning environment requires a broad range of basic scientific materials, as well as specific tools for particular topics and learning experiences. Teachers must be given the resources and authority to select the most appropriate materials...for students to participate actively in designing experiments, selecting tools, and constructing apparatus, all of which are critical to the development of an understanding of inquiry.

Program Standard D states, in part, "Conducting scientific inquiry requires that students have easy, equitable, and frequent opportunities to use a wide range of equipment, materials, supplies, and other resources for experimentation and direct investigation of phenomena." This standard also points out the need for suitable tools for measurement and data analysis and that "good science programs require access to the world beyond the classroom". Advances in graphing calculator-based data-gathering devices have made them a versatile tool to help teachers and students achieve the standards.

Teachers Teaching with Technology (T^3) is an international organization supported by Texas Instruments. This group of teachers-supporting-teachers is heavily involved with promoting the most appropriate use of technology for learning. T^3 provides extensive professional development to teachers wishing to learn the skills and pedagogy associated with using hand-held technology products—such as graphing calculators and data-gathering devices—with their students. T^3 Canada is in the process of creating the Pan-Canadian Science Institute (PCSI) (Teachers Teaching with Technology, 2001) as part of their professional development offerings. T^3 institutes are four to five-day activities designed to provide participants in-depth experience with suitable technology and pedagogy in the theme area of each institute.

Rationale for My Involvement

I am fortunate to have been trained and certified as a T^3 Instructor and, as such, I am a facilitator of professional development for teachers and professional development groups. I have been involved as one of the primary planners and resource package authors for the PCSI. Our T^3 team has created and assembled materials for the PCSI; however, this institute has not yet been formally offered. As I will be one of the first to facilitate this institute, I have a vested interest in ensuring that this institute does as much for teachers, and ultimately their students, as possible.

My particular interest in this project lies in my beliefs about the use of technology. I believe that technology can have a positive impact on students if it is used effectively. Effective use of technology requires the understanding that technology is a tool to aid learning and not an end in itself. In order to be effective, the use of technology must be implemented in classrooms and integrated into teaching practice. To be effective, the technology must not only be used by the teacher, it must also be available for use by the students; and it must be used by both in suitable contexts. Another strong belief I have is that too often professional development activity, although valuable, is wasted due to low implementation rates. I have experienced this personally both as a participant in, and a facilitator of, professional development activity. A few years ago, at the end of the school term, I took part in an excellent workshop on a particular curriculum topic. Before the next term, my workload changed, and I had not used any of the skills I learned in that workshop. Today, I would have difficulty implementing those skills even though I still remember how worthwhile I felt the workshop had been at the time. Similarly, I have facilitated many teacher in-service programs on a new computer software program. Several teachers have told me that they will need to participate in the in-service again because they did not have access to the software in their own schools. Their learning was lost because they were not able to use it soon enough.

Analysis of my own use of technology in the classroom is biased due to my own skill, experience, and enthusiasm. This project allowed me to test my beliefs—that effective use of technology has a positive effect on students, and that professional development effort is not wasted if it is implemented—by following a varied group of science teachers, with little initial skill or experience in this technology, and monitoring the implementation process in their own classrooms.

My particular involvement in T^3 and the PCSI makes the investigation of the effectiveness of this professional development activity relevant and important to me as well as to T^3 and other professional development providers.

The Pan-Canadian Science Institute (PCSI)

The purpose of the PCSI is to help teachers develop suitable attitudes, skills and knowledge to use graphing calculators and linked data-gathering devices effectively and appropriately to enhance student learning in science classrooms. Most high school mathematics classes already use graphing technology as part of a curriculum mandate. For example, the Alberta Applied Mathematics 20 course requires the use of a graphing calculator (Alberta Learning, 2002), and *Applied Mathematics 11* (Alexander et al, 2000)—currently the only approved resource package for Applied Mathematics in Alberta—uses the TI 83™ graphing calculator and CBL™ data gathering system for examples and for many investigations where data is gathered to provide a context to apply the mathematics. Similar expectations exist throughout most high school mathematics programs. However, most students and teachers are unaware of the wider potential of hand-held technologies. Using these devices more fully and in varied settings makes better use of this resource, encourages cross-curricular connections, and helps prepare students to use effectively a wider variety of technologies, which they will eventually encounter in the workplace.

The overarching themes of the PCSI include teacher technical skill development, consideration of the nature of science, science education principles, and learning styles of participants and students in general. The PCSI explicitly provides teachers with the skills and knowledge they will need to use the graphing calculator and related technologies with confidence. Also, there are explicit modeling and discussion of appropriate use of technology for learning enhancement and such issues as evaluation with technology, budget, management of materials and student activity, and cross-curricular and real-life connections. The Pan-Canadian Science Framework (CMEC, 1997) provides specific contexts for much of the activity of the PCSI, thus making the institute directly relevant to the classroom. For example, the PCSI Activity 2.5: Acid-Base Titration (Teachers Teaching with Technology, 2000) correlates directly with specific learning outcome 213-3 for chemistry from the Pan-Canadian Science Framework, which states, "students will use instruments effectively and accurately for collecting data (e.g., manipulate burettes and other instruments used for titrations)" (CMEC, 1997). PCSI Activity 3.2: The Rocking Critter: Simple Harmonic Motion addresses the Alberta Learning Physics 20, Unit 3, Major Concept 1, "many vibrations are simple harmonic" (Alberta Learning, 1998); and PCSI Activity 3.3: Merry-Go-Round addresses the Alberta Learning Physics 20, Unit 2 STS Connection of "understanding uniform circular motion…in the context of…the motion of carnival rides and playground equipment moving in horizontal or vertical circles" (Alberta Learning, 1998).

The PCSI engages the participating teachers in their own learning with a focus on their own applications in the classroom, as well as encouraging them to look at the broader perspectives of planning to assist their colleagues and their students in their own schools. By design, the participants are encouraged to work with teachers from other settings, with different teaching backgrounds, and from different disciplines. As a by-product of activity, mentoring, coaching, discussion, reflection, demonstration, research, and reading, most participants gain a deeper understanding of a pedagogy of science education, a positive attitude towards alternate learning modes, and a wider understanding of science topics and applications.

Once the teachers participating in this project completed the PCSI, they were encouraged to work collaboratively to assess and improve their implementation practice and to assess the impact the use of this technology has on their students. This project was an attempt to discover the effectiveness of the PCSI in providing teachers with the technical skills to use calculator-based data-gathering technology, to determine how much of this skill is transferred to the classroom, and to determine how best to improve the implementation process for future groups of teachers.

Research Questions

Professional development is an important component in education. More and more recognition is being given to the importance of teacher professional development as a way of improving student learning. Professional development has earned contractual obligation, responsibility, and accountability. The role and process of professional development activity is evolving but must overcome a great deal of inertia of tradition. Despite a great deal of evolution in professional development programs, even today, much of the professional development activity that takes place in our education system involves teachers attending conference or workshop sessions in relatively large groups to hear about, see, or try some new skills; or to gain some new knowledge. The activities can be very interesting, very well planned, and pedagogically sound; however, putting the new skill or knowledge into practice may not be easy nor happen to the extent that would be most beneficial. Teachers spend a lot of time and effort in developing lesson plans, assignments, and activities that work for them in their classes. To make significant changes in classroom practice means doing more work and perhaps discarding some of the sweat-equity that took a lot of energy to develop. It is too easy to learn some interesting things at a workshop but then continue along with the same methods and materials that have been used before. How effectively new teacher skills and knowledge are transferred from a workshop setting to actual classroom use is an important issue.

In this project, I followed a group of teachers as they took part in an intensive professional development institute—the PCSI—and began the process of implementing their new skills into their classroom practice. Through this year-long project I attempted to answer the following three questions: (a) How effective was the PCSI in providing the teachers with new skills and knowledge, (b) to what extent were the teachers able to implement their new skills and knowledge in their classroom practice, and (c) what impact did this have on students in the classroom?

Literature Review

Professional Development

The education community recognizes that teacher professional development is necessary. Professional development occurs in a wide variety of modes, is organized at a wide variety of levels, and involves many sectors in the field of education. The importance of professional development is well documented and supported by many different types of projects (Gess-Newsome, 2001; Eisenhower National Clearinghouse, 1999). Locally, in 1995, Alberta Education, the provincial ministry of education, provided funding to set up and support six regional professional development consortia to address regional professional development needs and issues. The value of the work done by the consortia resulted in continued funding (Alberta Learning, 1998)[1]. In Ontario, the Education Improvement Commission conducted extensive surveys and research across the province. As reported by Morey (2001), in their January 2000 report, *A Report on Improving Student Achievement*, the commission acknowledges a correlation between student learning and teacher in-service professional development. It recommended quadrupling the amount of funding being spent on professional development in Ontario. In 1998, following the approval of new mathematics curricula as part of the Western Canadian Protocol, I was directly involved with educators, education ministries, and businesses with education support components—such as Pearson Education and Texas Instruments—collaborating to develop and provide a variety of professional development opportunities relating to the use of newly mandated technologies and approved resource

[1] The Alberta Regional Professional Development Consortia have been very pro-active in making professional development activity more effective. My work with the Consortia has been an important prelude to this project, and the outcomes of this project will be important for some future Consortia planning.

materials. A wide range of professional development activities were offered with the financial support of the businesses and the cooperation of provincial ministries, regional consortia, and local school districts.

Teachers engage in a wide variety of professional development activities, both formal and informal. Participation is high. A survey conducted by the Canadian Teachers' Federation in 1998 "showed that 85.5 per cent of Canadian teachers completed one or more formal learning courses or workshops in the previous 12 months" (Browne, 1999). A 1999 survey by the Ontario College of Teachers identified a wide range of largely self-directed informal learning activities in which teachers participate. These include reading books on specific areas related to teaching, regularly reading in education or professional journals, researching a question through library or internet searches, making presentations on education topics or issues, mentoring, involvement in professional organizations. . . .

Given the necessity of professional development, and the amount of time and resources spent on it, it is important that any professional development activity be effective and efficient. Professional development, or professional learning, is like any other learning process. Each person is an individual with individual needs, backgrounds, goals, and styles. To be effective, a professional activity should fit each individual's needs and styles as well as possible. However, development is personal. It cannot be forced, but only stimulated through outside agents (Clark, 1992).

Literature supports that teacher input is important to successful professional development. "Designers of effective professional development experiences pay close attention to the expressed interests and needs of the participating teachers," (Vasquez and Cowan, 2001, p. 14). In a review of research, Gess-Newsome (2001) summarizes characteristics for successful professional development for science teachers. Effective professional development: (a) Includes sustained support, (b) is designed by and for individuals, (c) is connected to classroom practice, (d) helps teachers learn science content in new ways, (e) challenges pedagogical beliefs and practices, (f) promotes incremental change, and (g) provides for collaboration. Hassel (2001) also describes high-quality professional development in terms of being collaborative, current, embedded in daily school life, having long-term substantial support, and enabling development in subject content, teaching strategies, technology and other teaching elements. But, as Guskey (2000) points out, despite the popularity and perceived value of professional development activities, we still know only a little of what difference they make.

This project attempted to model, in the particular PCSI context, what literature says is good professional development (Hassel, 1999; Rhoton and Bowers, 2001a; and Rhoton and Bowers, 2001b). The PCSI was designed by a team of practicing teachers and experienced professional development designers. The participants attended voluntarily and had a wide range of choices for their activities. The relevance of the activities was regularly emphasized, a wide range of learning styles was accommodated, and learning was integrated in practice and grounded in theory. Participants were encouraged to learn from each other and to cross discipline boundaries. Directed activities, open explorations, and trial and error experimentation were all provided as hands-on activities; pedagogical and logistical issues, reflection topics, and planning scenarios were raised to stimulate discussion and personal writing. The teachers were asked—and regularly reminded—to consciously assume several roles: novice learners of the technology, science teachers implementing the technology, students of science, and professional educators.

Participants were given all the help they needed, yet, at the same time, situations were created where they needed to work collaboratively or independently. Regular debriefing sessions were held throughout the PCSI, at the end of the PCSI, and throughout the implementation study period. Participants were also provided with scheduled follow-up support in their own classrooms and were given access to a variety of support options on an as-needed basis. Throughout the project, teacher learning and activity was refocused on good science learning principles: inquiry, data gathering, record keeping, analysis, and modeling. All of this was provided in order to glean information on how teacher learning as a result of this specific professional development activity is implemented into the science classroom, and to determine how this impacts students.

Instructional Technology in the Science Classroom

There is a great deal of literature on implementing instructional technology into the classroom and its impact on students. However, the term *technology* is almost invariably limited to mean computers. Research on how hand-held, calculator-based technology impacts the classroom is overwhelmingly related to mathematics, rather than science, and is well summarized in a research report commissioned by Texas Instruments (Texas Instruments, 2002). Personal conversation with Renee Hartshorn, the T^3 Professional Development Programs Manager, revealed that there has been very little research in the use of hand-held probeware in science. There is, however, a useful body of literature on the use of microcomputer-based learning (MBL) or instructional technology (IT) in science education[2]. The use of MBL or IT as an effective tool in science to help build conceptual understanding and to improve student ability to interpret

[2] For an excellent bibliography see Bell and Bell (2003).

and understand many forms of data plots is supported by Redish, Saul, & Steinberg (1997) and Svec (1999). Ng and Yeung (2000) document some potential problems in using IT: students are easily bored if there is not an adequate amount of equipment as those who are more IT competent monopolize its use, and students can also be bored by just following directions and watching equipment. They suggest, however, that with appropriate teaching methods, there are substantial opportunities for guided investigative work, and higher-level thinking and analysis on the part of the students. Graphs, often an end-point in the experiment, now become a starting point for student learning. In order to obtain widespread use of appropriate methods, Ng and Yeung claim, "there is an urgent need for in-service training of physics teachers on the effective use of data-loggers." Gipps (2002) recognizes some of the same potential learning opportunities with IT data loggers when suitable teaching methodologies are used. He stresses the importance of the role of the teacher in guiding the students as the technology automatically does what formerly took most of the students' time in an activity. He also points out how the teacher can adapt the technology to fit learning needs. Newton (1998) admits that many teachers use IT because it is mandated; however just gathering data with technology is not enough. In fact, using data logging may result in a poorer practical science experience for students than traditional methods unless careful consideration is given to what the students should do with the data. Data gathering time can be used to observe, question, and discuss what is happening; with suitable software, data can be explored in ways that were impossible with pencil and paper methods. Since hand-held technology has reached virtually the same capabilities for data-gathering as the computer-based systems had a few years ago, it is valid to consider the MBL or IT research in the context of this project.

The use of hand-held technology in the science classroom is becoming more common. The influence of curriculum standards (Council of Ministers of Education, Canada, 1997; National Research Council, 1996), movements in standardized assessment towards including questions related to lab activities (Alberta Learning, 2003), and positive reports by teachers (Schneider, 2001) all put some pressure on teachers to move in this direction. There is also a public expectation to integrate technology in the classroom (Barr, 2002). Given the fact that hand-held technology is now used widely in high school mathematics programs—and thus already in the hands of many students—it only makes sense that science programs should make wider use of the skills many students already have with this technology. Massey (1999) points out that the use of graphing-calculator-linked probeware is affordable, versatile, portable, compatible with computer presentation software, and quicker at data collection than traditional methods, thus providing more time for instruction or further experimentation. Wetzel and Varrella (2000) argue that the use of this type of equipment for hands-on student use is also easier, safer, and more precise than traditional methods.

Laboratory work is important to both attitude and learning (Freedman, 1997). Schneider (2001) reports gains in student interest and performance in his chemistry class, and Massey (1999) showed statistically significant increases in student attitudes towards science, both through the use of graphing-calculator-linked probeware in the hands of students. Michaelides (2000) outlines some advantages of implementing hand-held data-gathering equipment in the classroom such as: (a) compatibility with educational standards, (b) links to reality, (c) saving classroom time, (d) simplicity and portability, (e) cost effectiveness, and (f) the availability of a variety of probes, features and assistance services. It seems clear from the literature and trends in education that more science teachers should be learning to use hand-held data-gathering technology.

Implementation Issues

Despite the many arguments in favour of using graphing-calculator-linked probeware for student hands-on activity in science, there are a number of issues that impede its implementation. From my own experience working with teachers I have encountered arguments against using this technology in the science classroom because of: (a) perceived lack of classroom time, (b) inability to work through technical issues, (c) lack of funding for hardware, (d) lack of interest and time to participate in necessary professional development, and (e) obvious—yet unarticulated—fear of embarking on a new course of action. Michaelides (2000) outlines some challenges to the use of this technology including: (a) lack of familiarity with the devices, (b) technical difficulties, (c) unfriendly menus, (d) relatively small screen size, and (e) equity of availability of all needed equipment. Wetzel (1999) expands on a number of barriers to implementing technology in science education including: (a) lack of time, funding, access, training and support, and a vision or rationale; (b) assessment practices; (c) teacher apathy; and (d) teacher involvement. Most of the components of Wetzel's *ST⁴AIRS* model[3] for overcoming the barriers were included this project. Wetzel and Varrella (2000) point out that teachers have difficulty in shifting paradigms from the lecture and so-called *cookbook* lab activities mode they learned to more investigative and versatile use of technology-in-the-hands-of-students methods that are now possible. Rubba (as cited in

[3] ST^4AIRS stands for Support, Time, Training, Trainers, Transition, Access, Involvement, Recognition, and Staff development.

Wetzel and Varella, 2000) argues that successful implementation of technology in classroom practice cannot be expected from teachers having little background or experience with the technology. This is supported by Guskey (2000), who points out that early implementation is complicated by multiple, pervasive, unanticipated, and context-specific problems. He claims "no one expects new learning to transfer immediately into more effective practice" (p. 180). Given teachers' general desire to do their best in the classroom, this becomes a chicken and egg type of issue: implementation is not likely without background or experience, yet background and experience come through implementation.

An important factor for successful implementation of any professional development is follow-up. Guskey (1998) argues that follow-up is the key to successful professional development, but that it is often forgotten. Even if it is not forgotten, follow-up is often difficult to provide because of time, logistics, geography, and daily priorities. Joyce and Showers (1988) also maintain that follow-up is important, and they provide guidelines for different types of follow-up components. Follow-up was an important part of the design of this project.

Krajcik and Layman (2001) claim that the effectiveness of this type of technology depends on the teachers' understanding of how to use the technology, knowledge of the concepts involved, and knowledge of how to help their students link their technology experiences with relevant concepts. The prime focus of the PCSI is to explicitly provide teachers with these abilities, and the focus of this project is to investigate how this translates into teacher practice. Because the PCSI has not been held before, no one has done any research on its effectiveness as a professional development activity or its impact on teacher practice and students, and there is no published literature on this specific area. If for no other reason, this project is of interest to some people because it is the first investigation of the PCSI.

Methodology

Setting the Context

The focus of this project was to investigate the implementation of new teacher skills and knowledge gained through a professional development activity and the impact this had on classroom practice. In order to obtain a suitable baseline, I chose to use the PCSI as a context for the professional development. This also provided me with an added bonus of the opportunity to pilot and evaluate the PCSI in a real setting.

Through connections made at the T^3 International Conference held in Calgary in March 2002, I recruited a suitable group of high school science teachers from two convenient schools: École Secondaire Notre Dame High School in Red Deer and St. Francis Xavier Catholic High School in Edmonton. The science departments in both schools had obtained a variety of Texas Instruments hand-held data-gathering technology including Calculator Based Rangers (CBR™)[4], Calculator Based Laboratories (CBL-2™), and a variety of sensors or probes. In both schools, the TI 83^{+}™ was the standard calculator used in mathematics and was thus to be used also in science. Each science department had set itself a goal to learn more about using and implementing this technology in the science classroom.

Of the eight teachers who agreed to participate and completed the project participation agreement (see Appendix A), only one—who taught mathematics as well as science—was very familiar with the calculator. The others had little knowledge of the extent of the technology capabilities; several had very little experience with a graphing

[4] The names of the equipment mentioned throughout this project report are trademarks of Texas Instruments. Other manufacturers do make similar equipment.

calculator. The teaching experience of this group of teachers covered the full range of science courses normally offered in high schools; at least two teachers in the group taught each of Science 10, Biology 20 and 30, Chemistry 20 and 30, and Physics 20 and 30. During the course of this project, the teachers attempted to implement this technology in only one or two of their classes at a time.

I facilitated the PCSI for the whole group of teachers. We met for two days at the end of August 2002, just before the school term began. The remaining three days of the institute were spread through September. Some sessions were in Red Deer and others were in Edmonton. All teachers participated in all sessions. Throughout the Institute—and the project—the teachers were encouraged to work collaboratively and seek help at any time from me. The similar background, motivation, and needs of the teachers, as well as the uniformity of delivering the Institute, helped to ensure that their professional development experience was as uniform as possible as they began the process of implementing this technology into their individual science classroom practice.

Data-Gathering

This project operated at different levels and data was gathered to evaluate or understand what happened at each level. The nature of this project allowed us to evaluate the suitability and effectiveness of the PCSI, observe and assess the implementation process, consider the impact on teachers in their practice and attitude, and consider the impact on students. Different sets of data were gathered through several different methods. The quantity of data varied from several hundred student-surveys completed, to only eight teachers providing data. The raw data will be securely stored in my Red Deer College office for a period of three years from the completion of this report.

The teachers independently completed a survey of skills and knowledge pertaining to the use of this technology (see Appendix B). The survey consisted of a self-evaluation on forty-three specific calculator and data-gathering skills, and a set of open-ended written response questions. The specific skills were scored on a five-point Likert scale ranging from 0 (no knowledge or skill) to 4 (could show others). The written responses were designed to assess the teachers' awareness of the technology capabilities and understanding of important implications of the technology implementation. I piloted the survey with a group of Calgary teachers in June 2002 at a teacher workshop on data-gathering; only slight modifications were made. I administered the survey three times: immediately before the PCSI in August 2002, at the completion of the PCSI in September 2002, and towards the end of the project study period in May 2003. This survey was intended to determine any changes to individual teacher's knowledge and ability during the PCSI, and any further changes—positive or negative—during the implementation study period.

At the conclusion of the Institute, each teacher completed a PCSI evaluation survey (see Appendix C). This form consisted of thirty items related to the Institute scored on a five-point Likert scale indicating very poor to very good, and seven open-ended written response questions asking for opinions and suggestions about the Institute.

An important part of the PCSI is teacher consideration of pedagogy within their individual contexts. A number of activities in the PCSI included reflection on pedagogical and practical issues. At the beginning of the PCSI, I gave each teacher a notebook in which to record reflections. Throughout the implementation period, I raised more issues and encouraged the teachers individually and collectively to continue reflecting on their work, identifying issues, and recording their thoughts and processes[5]. From the beginning, I asked that any or all volunteer to share their notebooks with me at the end of the project for the sole purpose of gathering information. Several did share their notes with me; others provided collective notes on their collaborative implementation work.

During the implementation period, I visited several class sessions where students were using the data-gathering technology in their work. I observed the instruction process and the class activity, and spoke with students as they worked with the technology. I was also invited to work with some of the teachers as they prepared new lesson activities for classroom use. My notes and reflections from these visits provided some valuable insights.

The participating teachers agreed to assist me in gathering student data. Each teacher chose one or two classes for study purposes. The teachers obtained permission for student participation (see Appendix D) and administered a student survey (see Appendix E) at the beginning of the term and again at the end of the term. The student survey consisted of a list of thirty-five specific calculator and data-gathering skills. The students were to check those skills in which they believed they were competent and those skills that they had seen performed in their science class.

Near the end of the project study period, I made arrangements to formally interview each participating teacher, the principal in each school, and a selection of

[5] This is a simple model of action research. At the beginning of the project I had hoped to establish formal action research groups with the participants in each school. This proved to be too much for the group and I decided that it would be more useful to continue to focus on implementation issues.

students. In order to maintain some consistency, I used a protocol outline for the forty-five minute teacher interviews (see Appendix F). I chose to use a focus group format (see Appendix G) to gather opinions and information from the students. To select the students for the focus groups, I asked each teacher to nominate three to six students who had completed the study participation permission forms and who would be likely to cooperate openly in a group. To ensure a good cross-section, I randomly selected two nominees from each teacher to form focus groups of eight students. Through the teachers, and several days in advance, I invited the selected students to join me for pizza and pop during lunch break to discuss their opinions and ideas about data gathering with the graphing calculator in science class. I held two such focus groups at St. Francis and one focus group at Notre Dame. As the results in all three groups were very similar, I decided that a fourth focus group would not be necessary.

At the end of the project period, I invited all the participating teachers to join me in a wrap-up dinner meeting. At that half-day meeting, I identified and solicited issues, and checked the teachers' perceptions on these issues. I then shared my findings from my analyses of all the data collected and asked for their thoughts and conclusions from my analyses. We shared our perceptions on all aspects of the project. We compared the similarities and the differences between the experiences of the two schools. We collaborated to provide a collective view of their personal and professional growth in relation to this project, the impact on their classroom practice, and their perception of the impact on students. We also made some recommendations aimed at other similar groups of science teachers considering implementing this technology.

<u>Analysis</u>

The variety of data collected in this project dictated a variety of analysis processes. Some of the data were numeric and allowed some simple statistical analyses; other data were anecdotal and required summarizing and organizing to find trends or themes.

From the teacher skill surveys, I entered the numeric data into a spreadsheet with three columns for each teacher corresponding to the pre-institute, post-institute, and final survey; and I calculated the average scores for each item for each survey. I found the differences between pre-institute and post-institute, pre-institute and final, and post-institute and final on average scores; and I highlighted any decrease in score on any item (see Appendices H and I). Because of the small sample size, I performed a Wilcoxon signed-rank test as described by Triola, Goodwin, & Law (2002, p. 643) to determine the statistical significance in the average score differences. I summarized written comments and noted common themes.

I also entered the PCSI numeric evaluation data on a spreadsheet (see Appendix J). I calculated average values and the standard deviation for each item. I summarized written comments and noted common themes.

I coded data from student surveys in a spreadsheet in the form of a blank cell representing an item not checked and a value of 1 representing an item checked by the student. As individual students were not identified, I totaled the scores from the student surveys for each item in each class and calculated an average percentage positive response for each item in each class. I determined the difference between the initial and final positive response rates for each item in each class, highlighted any decreases, and then averaged the values for all classes (see Appendix K).

I summarized notes from class observations and teacher and student interviews. We discussed and interpreted the notes within the teacher groups. We developed themes and trends and collaboratively made a set of conclusions and recommendations at the final project wrap-up meeting.

I attempted to verify any themes or trends by soliciting anecdotal data from several sources. For example, I determined student perceptions directly through the use of a survey, focus group interviews, and in-class observations and conversations. I confirmed my conclusions by checking teacher perceptions of student reactions as well. I also used multiple methods of gathering teacher data including surveys, individual interviews, group meetings, observations, and discussions.

Findings

This project produced a wealth of learning for the participating teachers. Although we attempted to document as much as we could, much of what was learned is at a level beyond the written word; it has gone to the heart of some very good teachers. The experience is always individual and more than can be described in a few pages. Nevertheless, some highlights that I observed, that were described in interviews, or that were written about in the journaling process are worth mentioning.

The most meaningful learning for most of the participants occurred incidentally while working or discussing with colleagues. This was true during the PCSI and throughout follow-up activities. The synergy of the group was evident from the beginning. One example of incidental learning occurred during a titration activity using a pH probe. A participant talked about alternative methods of finding titration end-points which prompted another participant—from a different school—to experiment with different probes to find endpoints. This turned into a mini-project presentation where everyone learned more about chemistry, use of the technology, and compatibility of different probes.

A second form of highlights for the project participants was the opportunity and encouragement to establish a broader colleague network. Although the sub-groups in the project worked and met together in their respective schools, the context of this project gave them a focus. In particular, I observed a strong, mutual support develop in one of the sub-groups. These teachers helped each other out in ways beyond what normal colleagues would do. They shared trouble-shooting tasks, collectively asked for consultative help, collaborated on activity materials and worked through on-going revision, and ultimately prepared to take on the political challenge of expanding the use of this technology throughout their entire science department.

Pan-Canadian Science Institute

In December 2002, I sent a detailed thirty-two page report, *The T^3 Pan-Canadian Science Institute Evaluation Report* (Williams, 2002) to the Texas Instruments Professional Development Managers. The PCSI evaluation survey data (see Appendix J) clearly show that the PCSI was a success. A numeric rating scale of 1 (very poor) to 5 (very good) was provided for every component and many sub-components of the PCSI. None of the group average scores for any question were less than 3.0. The overall average rating for all components by the entire group was 4.5.

The written comments also indicate a very high participant satisfaction rate. Two outstanding components of the PCSI as noted by the participants were the individual project presentations and the opportunity to work closely with teachers of different background and skills. The individual project presentations were without doubt the best part of the institute. The quality of projects showed an extent of learning and confidence with the technology that inspired everyone. The comments indicate the high quality of the participants and the importance of including this type of component in professional development.

The growth in breadth and depth of the participants' technical knowledge and skill shone through as the teachers worked and learned together. Initially, several of the teachers were very hesitant—perhaps even fearful—of using the hardware. They were confused by the many keys and keystroke patterns, lost in the screen menus, and generally overwhelmed by the amount of information presented. Once they worked through some preliminary activities and saw some of the capabilities of the calculator, they began to explore its use. Once they successfully completed a data-gathering and analysis task on their own, they were ready to set their own directions for learning. The PCSI was designed to encourage participants to choose or create options in the use of the technology to fit their individual classroom needs. At the same time, the teachers were encouraged to share their difficulties and insights with others. By working collaboratively with the technology, they learned different ways of setting up experiments, of gathering and displaying data, and of analyzing the data. More important, they learned about different ways of approaching or understanding a science topic; they learned about some science outside their own discipline; and they learned more about different perspectives on teaching as well.

Teacher Perspectives

This group of teachers had a wide variety of teaching experience from only a few years to over twenty years. The average years of teaching experience was just over ten. Some have been using a graphing calculator for many years while most were just beginning. The average experience with using the graphing calculator was 5.5 years. Most were very new with graphing calculator-based data-gathering. The average time since first having heard about the data gathering capabilities of the calculator linked to a CBL™ system was 3.1 years.

The PCSI was a suitable and effective professional development activity for the teachers. Teacher survey data (summarized in Appendices H and I), supported as well by interview data, show that the teachers did increase their skill and knowledge in the use of the hand-held data-gathering technology during the PCSI. Average survey scores for all items in the teacher survey increased from 1.94 to 3.48 during the course of the PCSI. All items had an overall positive average gain. Five items (#3, 4, 13, 27, and 28) showed a decrease in score for only one person each—and not the same person for each item. On these items, the Wilcoxon signed-rank test still indicates a statistically significant increase at the 95% confidence level for items 3, 4, and 13. The results on items 27 and 28 were inconclusive because the sample size was too small, but these items were not part of the PCSI anyway and can be considered control items.

Teacher growth can be seen in both survey data and anecdotal data from observations, interviews, and conversations. The survey data show a significant increase in skill and knowledge through the PCSI followed by slight declines in most items through the school term. Our interpretation of this is that the PCSI was very successful in providing the teachers with skill, knowledge, and confidence; and that use of the skills is important to maintain them. The confidence manifests itself in some slightly elevated scores at the end of the Institute in some items that were not taught in the Institute, for example item numbers 7, 8, 9, 10, and 13. During the implementation period, scores for those skills that the teachers used in the Institute but did not use in the classroom dropped the most. One factor that lowered the final score averages was that one teacher, due to a variety of factors, made little use of the technology. That individual's final scores dropped enough to make the group averages lower; if those scores are ignored, the number of items that decrease during the implementation period is noticeably diminished.

Anecdotal data analysis produced several unsurprising themes. "Use it or lose it," was unanimously supported by teacher comments. Skills that the teachers did not use in the classroom, or regularly on their own, were diminished. A second key for the teachers was collaboration. Those who had the least collaborative opportunities used the technology less often and lost more of their skill. Those who were able to collaborate most closely not only maintained their skill better, but also improved some skill and increased their motivation. A third theme arising from teacher interviews and conversations was the ability of the students to adapt to the technology easily. Given clear directions and guidance, the students learned the basics of connecting the hardware and using the DataMate™ software very quickly. Several teachers were very pleased with how some students even offered suggestions on how to improve the technology use in a particular context.

All the teachers have plans for continuing to use this technology. For the next school year some plan to use the technology more often with a wider range of activity; others plan more focused use to try to reach higher levels of learning by more in-depth analysis and experimentation in fewer settings. All the teachers had positive comments about the technology remarking on how well it works, how fast it works, how good the data is, and how versatile the probeware is. Some concerns about possible future issues included the uncertainty, as yet, of the durability of the equipment, issues about battery expenses, concern for consistency of student use opportunity within the school, and continuing professional development for themselves and—more important—for colleagues new to the technology.

Student Perspectives

I found the results of the student surveys, observations and focus group interviews to be very interesting. My interpretation of the student data was also confirmed by teacher perceptions of the impact on students. For the most part, the implementation of this technology to the science classroom was a non-issue for students. Students thought the technology was "cool", "not hard", and "fun". They were positive about its use as being the way it should be in our technological world. Some recognized a deeper potential of the technology to allow them to explore and learn more in the classroom. Many thought the technology was better only because it was more accurate—but could not explain how or why it was so.

The student skill survey data (see Appendix K) showed a few interesting things. As discussed in the next chapter, actual score values are not reliable, but the trends are unmistakable. Most of the students overestimate what they can actually do. Several items on the student survey (14, 24, 31,32 and 35) represent skills that very few students—and teachers as well—are likely able to do, yet, on average, seventeen percent of the students initially said they could do those things, and thirty-two percent claimed those skills on the final survey. In all classes, initially and in the final survey, students claimed to have more technology skills than they actually saw in their science class. The average percentage positive response for all skills in all classes for items they initially claimed they could do was fifty-one percent compared to thirty-six percent of the items having been seen in science. The final survey showed values of sixty-six percent that they could do versus forty-two percent of the items seen in science. In all items but one (number 11 as seen in science class), the student surveys show an increase in score from the initial to final survey. The greatest increase in scores occurred in those items related to data-gathering as performed in the science classes. These results match closely with what the teachers' perception indicated.

Our interpretation of the student survey results is that students had some degree of comfort and confidence with the use of the graphing calculator right from the beginning of this project. This is most likely due to students' use of the calculators in the mathematics program. During the course of the science classes, they learned more calculator-based data-gathering skill and were confident in their use of these skills.

An anecdote from observing a Chemistry 30 class describes the impact on students very well. The students were to investigate an exothermic and an endothermic chemical reaction by mixing different reagents. They had been given all the instructions and had previous experience using the technology. They were to use temperature probes connected through the CBL-2™ to their graphing calculator and set up the systems to plot real-time displays of temperature versus time. Two girls I worked with had little difficulty getting the experiment set up and running. They were able to correctly explain to me what they were doing with the technology and why. When they added the reagents for the endothermic reaction, the solution started bubbling vigorously. When I asked them what was happening, one of the girls quickly said it was boiling. I asked if it was hot and she answered, "Of course". The other girl was watching and obviously thinking. I asked them what the temperature was doing. They looked at the calculator display, briefly discussed their perceptions, and said the temperature was dropping. They then had an animated discussion, pointing to the bubbling and the calculator display, and quickly agreed that it was not boiling; there was a chemical reaction going on. The bubbling soon stopped and the temperature reached a minimum. As the temperature started to rise, I was easily able to start another discussion by again asking what was happening. This was a wonderful learning opportunity in chemistry for these two girls that took only a few minutes.

Afterwards, I asked the girls about how useful the technology was. Their comments were dead on. They said that last year they had to use thermometers, to read and record the temperature every few seconds, and then to go draw the graph. They did not really know what was going on until after they had drawn a graph and the teacher told them what it meant. On this day, they had been able to see the connection between the graph and the event. When they mixed the reagents, the bubbling started and the temperature started to drop. When the bubbling stopped, the temperature was at its coolest and then started to rise slowly as heat transfered from the room. They wanted to try it again, this time holding the reaction beaker in their hands to see if it would make a difference. They said they could think, talk, and ask questions while the reaction was happening instead of worrying about reading the thermometer every few seconds. They said the whole experience was—no pun intended—"Cool!"

Implementation Issues

The implementation process evolved in a very similar manner in both schools; almost all the teachers experienced the same phases of development. During the first few weeks of the extended PCSI, most of the teachers were challenged by the amount of learning they needed to do with the technology. There were some obvious concerns and frustrations—as well as excitement—with the wide capabilities of the technology and the amount of information to learn. A comfort level was reached quickly once the teachers experienced some success during the institute and started to help each other with ideas and difficulties. What initially seemed like major issues became routine procedures. Once the teachers began using the technology alone in their own schools, the focus shifted to exploring the technology and trouble-shooting. The main topics of discussion during the first several meetings were the difficulties encountered and associated resolutions, and the discovery of new activities or capabilities of the technology. This phase was very much teacher-centered in exploring the equipment capabilities and the teacher skills. As confidence and competence increased, the teachers began to focus more on the data that the technology could gather, and how to display and interpret the data in more meaningful ways. They were now linking the technology to their own curricula. Once they established a strong classroom learning potential the teachers began to focus on the student technical issues: What instruction will they need? How will the students access the software? How will the hardware be set up?

After one or two experiences with students using the technology, the teachers quickly moved on to pedagogical considerations: What student groupings will work? Should the students gather and interpret data in order to develop or discover a concept, or in order to verify a concept already presented in class? What form of data presentation and analysis will be most helpful to the students? At this same time, the real need to consider the impact the technology has on evaluation became apparent to the teachers. Should technical skill be tested? How valid are knowledge questions for student evaluation if they can be answered by the technology? How can higher-order thinking skills be evaluated through technology-assisted interpretation of data?

The final stage of implementation as observed at the end of this study is one of comfortable and competent use of the technology as a learning tool to promote student learning. Most of the teachers have discovered their own multiple ways of using the technology effectively. One teacher uses the overhead ViewScreen™ regularly by having students do in-class calculations for everyone to see. This helps tremendously in promoting proper calculator use and reduces the amount of calculation errors. Another teacher has a CBL-2™ connected to a calculator and ViewScreen™ and a few probes at the ready to do quick demonstrations as part of a lesson and in response to student questions or difficulties. All the teachers have worked on developing or adapting hands-on laboratory activities for their students. An interesting development is that the teachers in both schools have independently decided to develop a common introductory activity for students to learn the basics of data-gathering and interpretation, and—also independently—to develop a set of common, compulsory activities in Science 10 to be used by all Science 10 teachers[6]. The teachers have collectively prepared many activity packages for students and are well on their way to having their own Teacher Manual.

There are several implementation issues that were observed and mentioned frequently during meetings, interviews, and conversations. The most significant issue is that of teacher confidence in the ability to use the technology effectively in the classroom. During the early stages of implementation, the teachers were most concerned about getting the equipment to gather the data they wanted. Perceived technical difficulties and trouble-shooting took a lot time and energy. Those teachers that were able to work collaboratively with a colleague, or got some outside help, were able to move more quickly into classroom implementation. Once the teachers became confident in their

[6] It is important to note that the science department head in both schools was a part of this group. Both groups felt this step was important enough for student development that they would fight the political battle in their schools to implement this. They have administrative support and will likely succeed within only a school term or two.

abilities to solve or anticipate minor problems, and saw that students could work well with the equipment, they quickly learned to use the technology more effectively by going beyond just gathering data and challenging their students to observe, think, and analyze. Workshop follow-up and collaboration opportunities were very important in promoting successful implementation.

A second implementation issue is that of student skills. Even though the students claim to have a significant amount of calculator skill, the actual skill may not be suitable, and not all students have even the basic skills. It is not valid to assume that the students have the prerequisite skills and knowledge with calculators, data display, and analysis to move directly into data collection. The teachers in both schools independently recognized the need for some basic introduction to calculator-based data-gathering for students, which would include basic calculator skills, graphing, and analysis. They are planning to collaborate on an introductory science-based lesson with a simple measurement activity for their students.

Another implementation issue related to student skill is inconsistency within the school. Students catch on to the technology very quickly. If students have used the technology in an earlier class, they can—and want—to do much more with the technology in the next grade. This was seen even within only two school terms. As students progress through high school, it will be important to begin developing these technology skills in grade 10. But what about the students who did not have the opportunity to use the technology in their Science 10? To be most effective, the use of this technology should be implemented consistently in science school-wide. This has political and professional development implications within the science department and the school.

The last implementation issue identified is that of equipment. In order to use the technology effectively, there needs to be a sufficient quantity of working, up-to-date equipment that is easily accessible by the teachers. There are budget considerations in the purchase of the necessary equipment (see Appendix L), workload considerations for the set-up and maintenance of the equipment, and space and security considerations for equipment storage.

Discussion, Recommendations, and Conclusions

Discussion

The most important key to the success of this project was the group of participating teachers. These teachers not only volunteered for the project, but also were keen to participate. Both science departments had decided they needed to learn more about the use of hand-held data-gathering technology before they were aware of my project. Once we connected, it became a symbiotic situation; I provided them with the professional development they needed while they provided me with the context and the data I needed. The teachers had a vested interest in making this project a success. Both schools had spent a significant sum of money purchasing equipment. To have it sit without use would not bode well for any future equipment requests of any kind, so they wanted to be able to make it work. To a small extent, the teachers were dealing with some opposition from their own colleagues—not an unusual political situation in many schools. This was also a motivating factor. The initiative, motivation, enthusiasm, and dedication of this group of teachers allowed them to achieve a degree of implementation that may not be the norm for other schools.

There were many similarities between the two teacher groups and the two schools. Both schools had a significant amount of equipment that the teachers needed to learn how to use. Both had science department heads that enthusiastically participated in this project. With the exception of one teacher, the participating teachers had similar, limited knowledge of and experience with the graphing calculator. Both groups had administrative encouragement for the use of the technology and support for the necessary professional development to implement it effectively.

One of the initial goals of this project was to have the teacher groups participate in action research to monitor and improve their implementation. This has been successful in several school districts around Alberta. A model similar to that in *The Action Research Guide for Alberta Teachers* (ATA, 2000) was proposed. Despite some initial efforts to initiate this, the action research did not occur. This was too much to expect of teachers who were not only implementing a technology new to their school, but also learning the technology themselves. This project was not a high priority for the teachers; class work, learning the technology, and developing lessons were rightly more important. As they worked on different lesson plans and activities, they kept group binders and notes, which, along with regular meetings and discussions, worked well to provide some useful data, albeit less than rigorously documented. This served as a substitute for action research data.

Collaboration was a big factor in the success of individual teachers. Teachers collaborated strongly within their own schools and, to some extent, between the two schools. The teachers with the most success had the best collaborative opportunities—a participating colleague teaching the same course. Those teachers having a single class did not do as well at implementing the technology—nor maintaining their own skills—as those with colleagues implementing in the same course. The biology teachers had the toughest time because of the lack of a close colleague, and because of a perceived weaker fit of suitable technology activities within the biology curriculum.

There were some inconsistencies in the student skill survey administration. Although I conducted a pilot of the survey with some family high school friends, it turned out not to be an accurate representation of a whole class who did not know me nor have any interest in my study. The participating teachers—who initially thought the task was clearly described—administered the survey. As it turned out, student effort, honesty, and understanding were not consistent. The large quantity of data supports the clear trends shown, although the numeric results are suspect due to some flaws in the data. A check of teacher perceptions of student skill also supported the findings.

Numeric scores do not tell the whole story. Some items in both teacher and student surveys were included even though the topics were not covered in the PCSI and not likely to be a part of a science class. Scores on these items should not be expected to increase, however, there was a slight increase as teachers became more confident and explored the technology possibilities on their own. Scores that were initially very high had less room for improvement; scores that were inflated due to confidence or recent practice had the most potential to decline.

Anecdotal data came from classroom observations, interviews, conversations, and written comments or notes. Although there was some variety in the comments, there was a great deal of consistency in the themes and trends. In this report, I included anecdotal interpretations or trends only if they were repeated in different sources or contexts. As much as possible, I checked teacher perceptions of student reactions before providing the teachers with the actual student data.

Recommendations

The recommendations are presented here through the collaborative efforts of our participating teacher group. I facilitated a number of break-out sessions to consider recommendations on different components of this project, and we merged the ideas from different groups to create an annotated list. These recommendations are aimed towards a high school science department that is considering getting and implementing graphing calculator-based data-gathering technology. The process is likely to take at least two years; there is some flexibility in the order of the recommended tasks.

Preliminary action. A school or science department considering the implementation of calculator-based data gathering in the science classes should begin by developing some staff awareness and enthusiasm of the potential of the technology to help teaching and learning in the science classroom. This can happen in several ways: (a) Bring someone who has used the equipment and can demonstrate its potential to a staff professional development activity, (b) send some staff to a conference or institute such as a T^3 International Conference or the PCSI, or (c) send some staff to a cooperating site where the technology is already in use. A key element in the early stages is to give some teachers hands-on experience with the technology in a science context.

Short and long-term planning needs to be addressed early, possibly with the assistance of an experienced consultant. Someone needs to identify those who are interested in implementing the technology and their sincerity in following through with the necessary professional development. A lot of frustration can be diverted if the planners can identify a variety of resources before activity begins. Professional development opportunities and providers, equipment loans, request proposals, and budget approvals are easier to arrange when more lead time is available. It is easier to change plans as situations evolve than to try to make and approve plans in a last minute scramble.

Equipment. As early as practicable in the process, the science department should obtain some equipment by borrowing[7] or purchasing it. A recommended beginning equipment list is located in Appendix L. Some of the hardware might be available in the school mathematics department. The key here is to have some basic equipment readily available so that interested teachers can play with it in a not-threatening manner, and thus become at least a little familiar with how it works and what some of its capabilities are.

As equipment is purchased, there are several issues to consider. The obvious issue of budget should be dealt with as early as possible. Although initially there may be a significant capital expense, if it is compared to the costs of some other expendables within science or other school departments, it may not be out of line. All equipment need not be purchased at once; it can be obtained as teachers develop the comfort and feel the need to use it. Early planning and justification, along with administrative buy-in, may help with budget approval. Other equipment-related questions to consider early include: from whom will equipment be purchased; where will it be stored; and who will look after maintenance? The resolution of these questions may impact other decisions within the department or school. Equipment preparation and maintenance may become a workload issue for a teacher or technician. Classroom location may become more—or less—of a concern depending on how accessible the equipment might be.

Student involvement with equipment is also an issue. They must use it regularly and often to make it worthwhile. It will be wise to set clear procedures for student use of

[7] T^3 offers a free workshop loan program whereby a school could borrow several class sets of equipment for the purpose of holding a professional development workshop or an evaluation session. A school or school district also could arrange for a customized T^3 Professional Development Package including a trained facilitator and an option to purchase some equipment at very good prices.

equipment in classroom activity and outside of class. Obviously, clear directions for students are always important. In order to make the students more confident with the equipment, both written directions, which include screen shots of the calculator menus being used, and ViewScreen™ demonstrations of software setup are useful. A clear diagram or photo of the physical apparatus and connections is also helpful for the students both during setup and cleanup. Carefully chosen student assistants can be very helpful—and enthusiastic—to set up, check, clean up, and maintain equipment.

Key people. Those interested or responsible for implementing this technology in the science program should be aware of a number of key people. Early and strong administrative support and involvement is very helpful. It is important to try to get a core of very interested people in different science disciplines to become more involved with the technology. The wider the use, the more capabilities will be discovered, which will lead to more interest and support. A wider involvement of teachers in the department will also be helpful for everyone learning the technology; the department will have a stronger base of technological expertise. It would also be advisable to find a mentor for the science teachers: someone who is familiar with how the technology works in science and could assist the teachers in becoming confident more quickly.

Professional development. To improve the likelihood of successful implementation of this technology, it is important to get hands-on experience for as many staff members as possible. The science department should ensure that at least a core of people, who are interested and willing to learn the technology, get the professional development help they need to move forward. Allow them the necessary time to become comfortable with the technology and able to deal with the quirks of this particular technology environment. The necessary professional development time and funding should be planned for early. The department should arrange to maintain some form of in-service follow-up support to keep motivation and interest levels up and to help keep frustration or overload levels down. Throughout the professional development program, there should be strong emphasis on the appropriate use of the technology as a learning tool and the pedagogical issues around its use, and not just on the technical skills.

As important as the initial professional development is, it will also be important to have some ongoing professional development plans. Informal professional development, or collaborative work, will allow teachers to share hints and new discoveries from their class work. This constant updating of skills will help keep teachers confident, competent, and current. More formal professional development, whether as group presentations or as allotted time and funds for individuals, may be needed as new software and hardware becomes available. It will also be crucial to have some sort of professional development or mentorship plan in place to assist new teachers to the science department who have not get acquired the technology skills expected by the department.

Implementation. Teachers should begin classroom implementation early and slowly. They should start with a simple activity that the teachers have done themselves. No matter how simple, teachers should test-run all activities and equipment settings before they are introduced in the classroom. (A good way of doing this is to have the teachers do a short peer-presentation for each new activity or probe use.) The first classroom use should consist of a single probe used in an activity that will allow for a basic data presentation (lists and graph) and analysis. In order to overcome the students' initial technology-learning-hurdle, teachers should use the technology as a tool in the context of science topics. Some teachers may prefer to do a class demonstration first, but be aware that demonstrations can easily be overdone and cause student boredom. Teachers should encourage the use and appreciation of the technology by asking questions answerable with the technology. The time when the equipment is actually gathering and recording data can be used effectively by observing, questioning, or discussing the activity process with the students. Teachers should encourage some variety or experimentation in the use of the probe for gathering data in the given science context, and gradually expand technology use as both the teacher and the students become comfortable. Do not be surprised if some of the students quickly advance beyond the teacher's skill; take advantage of it.

Throughout the first few terms of implementation, teachers should gradually expand their range of use of the technology, and always have students using it, too. Rather than using the technology just for the sake of using it, teachers should collaboratively look at their course plans to see where the technology has the potential be useful by increasing efficiency, student motivation, or opportunity for learning. Allow the course plans to evolve to include the use of technology; but do not forget that the very first exposure to all that this technology can do can be overwhelming.

Ongoing program maintenance. To maintain the effective use of the technology in the science program, it will be important to have some consistency for students within the department. Once they have seen the usefulness of the technology, students want to have it available in all their science work. Partial implementation in a department will depend on the individual teachers using the technology. For department wide implementation it will be necessary for those teachers skilled with the technology to work collaboratively with as many colleagues as possible. A useful activity is to prepare a community technology binder, note-book, or website to include information on topics such as trouble-shooting, activity ideas and hints, equipment lists, preparation time and hints, handouts, data samples, illustrative graphs. . . with the intent of creating some form of teacher reference manual and a student lab manual. Although activity manuals can be purchased, the process of creating or customizing their own activity handouts is extremely worthwhile for teachers. The process gives relevance and ownership to the materials, which is likely to increase successful implementation. Opportunities for collaboration are crucial. It might be helpful for an administrator to formalize collaboration events, or allow time and adjust space to promote informal collaboration.

In order to maintain the use of technology throughout the department, and to make the best use of student skills, the department should begin by having students able to use the technology in all science classes beginning in grade 10. This may involve some political and workload assignment issues. It may also mean further professional development, either internally or with the help of external providers. To facilitate consistent, school-wide use of the technology in science, the department should provide all the science teachers with a minimum of an introductory student lesson outline (see Appendix M for a skeleton outline) and a beginning data collection activity. To encourage ownership in this, a department should organize collaborative planning sessions as an in-house professional development activity. This planning group will likely have insights on how the technology can be useful in all science classes, and can continue their collaboration by creating an outline of potential learning objectives using the technology in all science courses in the school.

Lastly, administration should not overlook future staffing considerations in the use of the technology. Once a department has implemented the use of this technology, it would not be fair to replace a leaving teacher who has used the technology with a teacher who is unfamiliar with the technology, or worse, one who is unwilling to learn how to use it. Staff turnover may require a focused professional development program within the school. Currently, many new graduate teachers are unfamiliar with this technology. Learning this technology during the first year of teaching would be a challenge; a mentor would be a great help. This group of teachers recommends that the universities should provide pre-service teachers with formal training in use of this technology—a view that is supported by other research as well (Wetzel and Varrella, 2000).

Conclusions

How effective was the PCSI? The PCSI was a very effective professional development activity. Although the time commitment on behalf of the participating teachers was onerous, they learned a great deal. Their technical skills were much greater as a result of the institute; their knowledge of the technology capabilities increased significantly; and they demonstrated an understanding of appropriate pedagogical uses of the technology. The teachers gave high scores for the content, organization, and materials of the PCSI. The institute was a wonderful forum for collaborative learning.

To what extent did implementation occur? None of the teachers was able to implement everything learned in the PCSI; it would not be appropriate to do so in the context of a high school science class. Of the technology skills that would be suitable to implement in the classroom, most of the participating teachers successfully did so. Once the teachers made the commitment to have students using the equipment with the appropriate pedagogy in place, the teachers did not look back. It was not easy work; it took time and collaborative efforts. But the teachers who successfully implemented the technology into their course planning continued to improve on their knowledge of and skill with the technology.

A few of the teachers did not achieve significant implementation. The reasons for this included lack of planning time, perceived lack of opportunity within the curriculum, and an absence of colleagues willing to work collaboratively. Those teachers who did not implement the technology into their practice to any significant extent lost much of their technology skill and knowledge.

What was the impact on students? The impact on students was generally small but positive. Most students learned to use the technology very quickly, and liked it. Most were already comfortable—and many very proficient—with many forms of our modern-day, menu-driven technologies; many were already familiar with the calculator through their mathematics classes. In the classroom, students worked cooperatively. Those students who had some reluctance or difficulty with the technology had many willing hands to help them. Many students saw nothing extraordinary about using technology to gather data and followed procedures and answered questions just like in any other science activity. Some students, however, were quick to see the potential of the technology to explore other possibilities within the context of the activity. They were the ones who evaluated their data based on the graphic display and re-ran the experiment if the data was poor. They were the ones who used the data-gathering time to observe and question the process. They were the students who recognized, and took advantage of, the opportunity to ask "what if…", and then tried it with the technology. Negative student impact was minimal and small in numbers. A minimal positive student impact was wide-spread. Of significance was a small number of students on whom there was a very powerful positive impact.

Further Research

This project has opened many doors for further research. Not only are some research topics now more clear, but there are several more teachers interested in looking more closely at their practice and the impact their practice and the use of hand-held data-gathering technology in science has on their students. Both schools are ripe for some action research projects in their science departments.

One of the participating teachers commented that this first year was not a good year for research, but the researcher should come back in three or five years and see what is being done then. An interesting study might very well be to look at some of the same teachers in a few years to see how they have evolved in their practice. An even better study would be to look at a science department before they are aware of the potential of this technology and follow their progress for several years from the process of introducing the staff to the technology right through to having a few years of complete implementation.

A question that was discussed by the group early in the project is: What effect does the classroom use of this technology have on student performance? We agreed that this would be a valuable question to answer, but this group was not in a position to do so within the time framework of this project.

A comment that was repeated several times—by both teachers and students—was that groups were important in the use of the technology. One teacher suggested doing a study to determine the effect of having students work with this technology individually or in groups of two, three, or more, and trying to determine an optimal size group in this context. Participants in this project provided arguments for individual work to ensure satisfactory facility with the technology, for using pairs or threes to help share ideas and tasks, and against using groups of three or larger to discourage shirking of participation.

A final issue that was suggested to be worthy of further study is that of classroom time. There is no doubt that the initial introduction of this technology takes extra classroom time. Some teachers argue against implementation because the extra time cannot be accommodated in their particular curriculum. Others argue that the extra time is well spent as the use of the technology actually saves more time later on in the course or in following grades.

Without doubt, there are many other issues related to the use of hand-held data-gathering technologies in science classes that will be investigated. As more science teachers implement its use, some will want to prove some of the benefits; others will show some of the disadvantages, drawbacks, and limitations. And thus continues the evolution of one small aspect of education.

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Appendix A

Teacher Participation Agreement

Workshop to Classroom

This is a project to investigate the implementation of new teacher skills and knowledge with hand-held graphing and data-gathering technology, and the impact it may have on classroom practice and student motivation, attitude, and learning in a high school science class. This project is organized and facilitated by Paul Williams of Red Deer College in partial fulfillment of the requirements to complete a Master of Education degree from the University of Lethbridge.

As a participating teacher I understand that:

- I will fully participate in the Pan-Canadian Science Institute (PCSI) offered in August & September, 2002. During this institute, I will learn more about the use of the TI-83+ graphing calculator, especially in conjunction with the Calculator Based Laboratory (CBL) data interface and a wide variety of measurement probes. The focus of this learning will be for the use of this technology in an Alberta high school science classroom, including general science, physics, chemistry and biology. I understand that this will be a pilot offering of the PCSI and that I will be expected to take part in evaluating the institute by sharing my reflections on my own learning and my experience in the institute.
- I agree that I will become a member of an Action Research Group based in my school. The focus of the Action Research Group will be to study the process of implementing the technology, and related pedagogy, into my classroom practice; and the impact this may have on students. I understand that facilitation for this Action Research Group will be provided; and I will need to participate in regular (monthly or as determined) meetings, keep appropriate personal records or a journal, and share in the work of the group.
- As a member of the Action Research Group, I agree to assist in analyzing the data we gather, drawing conclusions, and preparing a report of our findings. I also understand that we will be expected to present our findings in some suitable forum so that our colleagues may learn from our experience.
- I understand that the timelines for this project extend from the end of August 2002 until the end of May 2003. Presentations of our findings may continue into the following school year.
- I understand that my participation is voluntary; and I may withdraw at any time without prejudice. Any personal information I provide will be kept confidential. My information and any data that I gather will be combined with all other information and data in the final report and will not be identified with me or any of my classes.
- I understand that two schools are participating in this project: one in Edmonton and one in Red Deer. I agree that I may need to travel to the other school for two or three sessions throughout the term of this project. I understand that every effort will be made to minimize costs, and that there will likely be a grant available to assist my

colleagues and me; however, I agree that I will seek personal professional development support and be responsible for my own expenses.
- I have, or will, include this activity in my Professional Growth Plan.
- I will abide by all FOIPP and Human Subject Research Ethical Policies that apply.

All data and information will be combined and summarized in a final report, copies of which will be sent to the participating teachers, the school district office, and the University of Lethbridge Faculty of Education. Data will be stored securely in my office for a period of three years.

I appreciate your support of this project. If you have any questions, or for additional information, please feel free to contact me, the supervisor of my study, and/or the University of Lethbridge Faculty of Education Human Subject Research Committee.

Sincerely,

Researcher	Project Supervisor	Human Research Chair
Paul Williams	Dr. R. Mrazek	Dr. K. Roscoe
Red Deer College	University of Lethbridge	University of Lethbridge
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Workshop to Classroom Research Project
Researcher: Paul Williams

I agree to voluntarily participate in this project as outlined in the Workshop to Classroom Teacher Participation Agreement.

Name: ______________________

Signature: ____________________________ Date: _______________

Appendix B

Teacher Skill and Knowledge Survey

Hand-held Graphing and Data-Gathering Technology
Teacher Skill & Knowledge Survey

Name: ______________

Date: ______________

The following survey is designed to provide a picture of your current knowledge of, skill with, and attitude towards the use of graphing calculator and data-gathering technology in a high school science class. This survey will be completed at the beginning of the project, at the end of the Pan-Canadian Science Institute, and again at the end of the project. Please use your professional judgment to rate yourself for each item according to your status at the time you complete this survey.

Please use the following scale for each item and circle the response that best describes your current status:

- 0 I have never heard of this on a calculator.
- 1 I have seen it before.
- 2 I have done this and could do it again with some effort.
- 3 I have done this frequently.
- 4 I could show others right now.

Graphing Calculator Functionality:

1.	Do a mathematical calculation	0 1 2 3 4
2.	Plot a graph of a given function (equation)	0 1 2 3 4
3.	Adjust the window (scales) of a graph	0 1 2 3 4
4.	Modify the graph appearance or display settings	0 1 2 3 4
5.	Adjust or correct mode and format settings	0 1 2 3 4
6.	Create "friendly windows"	0 1 2 3 4
7.	Trace intercepts, zeros (solutions) and interpolate from a graph	0 1 2 3 4
8.	Calculate intercepts, zeros (solutions) and interpolate values from a graph	0 1 2 3 4
9.	Determine the slope at some point on a graph	0 1 2 3 4
10.	Create a table of values from an equation	0 1 2 3 4
11.	Enter data into lists	0 1 2 3 4
12.	Plot list data as a scatter-plot	0 1 2 3 4
13.	Plot list data as a histogram (bar graph)	0 1 2 3 4
14.	Transfer information from one calculator to another (link)	0 1 2 3 4
15.	Move data between lists	0 1 2 3 4
16.	Save lists with names for later use	0 1 2 3 4
17.	Modify lists	0 1 2 3 4
18.	Use formulae to manipulate or calculate lists	0 1 2 3 4
19.	Do basic statistics on data lists	0 1 2 3 4
20.	Use curve fitting techniques to determine data best-fit models (regression)	0 1 2 3 4
21.	Graph a best-fit curve to compare to actual data plots	0 1 2 3 4
22.	Manage calculator memory	0 1 2 3 4
23.	Use variables and constants	0 1 2 3 4
24.	Create and store text and pictures	0 1 2 3 4
25.	Use calculator menus	0 1 2 3 4
26.	Run a program from the calculator	0 1 2 3 4
27.	Write a simple program for the calculator	0 1 2 3 4
28.	Design, write and edit programs to extend the use of the calculator	0 1 2 3 4
29.	Use calculator applications (APPS)	0 1 2 3 4

<u>Data-Gathering and Connectivity Capabilities:</u>

30.	Connect and operate a CBL or CBR…………………………………………	0	1	2	3	4
31.	Gather data with a single probe (data-gathering or measurement device)	0	1	2	3	4
32.	Customize data-gathering process; change data-gathering mode	0	1	2	3	4
33.	Customize probe selection………………………………………………………	0	1	2	3	4
34.	Automate data-gathering	0	1	2	3	4
35.	Use multiple probes to gather data simultaneously	0	1	2	3	4
36.	Follow a pre-designed procedure to do an experiment…………………………	0	1	2	3	4
37.	Customize a data-gathering experiment	0	1	2	3	4
38.	Create or design a data-gathering experiment	0	1	2	3	4
39.	Connect my calculator to my computer…………………………………………	0	1	2	3	4
40.	Download programs or APPS to my calculator	0	1	2	3	4
41.	Transfer data from calculator to computer spreadsheet	0	1	2	3	4
42.	Transfer data from computer spreadsheet to calculator…………………………	0	1	2	3	4
43.	Retrieve data from internet lists to calculator lists	0	1	2	3	4

Please provide a brief written or point-form response to the each of the following:

A. How often do you anticipate using hand-held graphing and data-gathering technology the next time you teach a science course?

B. Please list the range of uses of this technology that you would consider using the next time you teach a science course?

C. In your estimation, what is the most important capability of this technology in your science course?

D. How do you think use of this technology might impact how you evaluate students in your science course?

E. How do you think use of this technology might impact student learning in your science class?

Thank you for your valuable input!

Appendix C

PCSI Evaluation Survey

Pan-Canadian Science Institute
August 26 - September 25, 2002
Red Deer - Edmonton

Facilitator: Paul Williams

Evaluation

Please provide your opinion on the following aspects of this institute using the following scale:
1 = Of no use or interest: very poor
2 = Of little use or interest: poor
3 = Not sure, neutral, or no opinion
4 = Useful or interesting: good
5 = Very useful or very interesting: very good

The handout materials package (binder):					
Organization:	1	2	3	4	5
Content quality:	1	2	3	4	5
Content quantity:	1	2	3	4	5
Readability:	1	2	3	4	5
Layout:	1	2	3	4	5
The scheduling of workshop days:					
Timing:	1	2	3	4	5
Dates:	1	2	3	4	5
Length of Institute:	1	2	3	4	5
Topic/Activity Organization:	1	2	3	4	5
The activities offered or provided:	1	2	3	4	5
The venues:					
Red Deer College:	1	2	3	4	5
St. Francis Xavier:	1	2	3	4	5
Breaks and refreshments:	1	2	3	4	5
Meals:	1	2	3	4	5
The debriefing or issue discussions:	1	2	3	4	5
Your "homework" and reflections:	1	2	3	4	5
The Facilitator/Instructor:					
Effectiveness:	1	2	3	4	5
Knowledge:	1	2	3	4	5
Support provided:	1	2	3	4	5
The available equipment:	1	2	3	4	5
Sessions:					
"Hardware" instruction and practice:	1	2	3	4	5
"Data Plotting" instruction and practice:	1	2	3	4	5

"Analysis" instruction and practice: 1	2 3 4 5
Science connections and issues discussions and references:. 1	2 3 4 5
Authentic Assessment session: 1	2 3 4 5
The outdoors activities: 1	2 3 4 5
TI Connect session: 1	2 3 4 5
TI Interactive session: 1	2 3 4 5
Individual Presentations: 1	2 3 4 5
Technology issues discussions: 1	2 3 4 5
Other: ___________________:................................ 1	2 3 4 5

Please comment on the good and bad points of any aspects of this institute including those listed above. Your input is valued highly. You may respond anonymously if you wish, but please respond.

What changes would you make if you were in charge of organizing this event for some of your colleagues?

What aspects of this institute would you retain?

What would you remove?

What was the highlight of this institute?

What was the biggest frustration or least useful part?

What was the most valuable or helpful activity in this institute?

The least valuable or helpful?

Name (optional): ______________________________

Please make additional comments - positive and negative- and suggestions on any aspect of this Institute on separate paper. You may hand this in to Paul Williams, or mail your comments by regular or electronic modes to:

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Appendix D

Student Participation Consent Form

Dear Student and Parent/Guardian,

I am conducting a "Workshop to Classroom Project" to investigate the implementation of new teacher skills and knowledge with hand-held graphing and data-gathering technology, and the impact it may have on classroom practice and student motivation, attitude, and learning in a high school science class. I anticipate that students participating in this project will benefit by having the opportunity to learn new technology skills and have more varied and interesting ways to participate in science classes.

As part of this research, participating students will be asked to complete an anonymous survey near the beginning of the term and again near the end of the term. The survey will ask questions about how aware students are of the capabilities of graphing-calculator technology, and about their use of the technology in science. A small sample of students will be asked to participate in a 10 - 15 minute interview to share thoughts on how the technology was used in the science class. A copy of the interview questions will be given to students well in advance of any interview. A researcher may visit a science class while the teacher is using the technology with the class. The purpose of the visit will be only to observe how the technology is being used with students.

All information will be handled in a confidential and professional manner. No personal information will be collected or recorded. No data or information provided through survey, observation, or interview will be identified with any student or with any specific science class. All data and information will be combined and summarized in a final report, copies of which will be sent to the participating teachers, the school district office, and the University of Lethbridge Faculty of Education. Data will be stored securely in my office for a period of three years.

Any participation in this project is voluntary. As a student, or as a parent/guardian, you have the right to withdraw your participation and consent to participate at any time, without prejudice.

If you choose to do so, please indicate your consent for you/your son or daughter to participate in this project by signing in the space provided on the reverse side of this letter, and return this letter to the science teacher.

I appreciate your support of this project. If you have any questions, or for additional information, please feel free to contact me, the supervisor of my study, and/or the University of Lethbridge Faculty of Education Human Subject Research Committee.

Sincerely,

Researcher
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Project Supervisor
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Dr. K. Roscoe
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Parent/Guardian Consent Form

Workshop to Classroom Research Project
Researcher: Paul Williams

I agree to allow my daughter/son, ____________________________(name), to participate in this research project as indicated below:

Complete surveys: yes ____ no____
Participate in interview: yes ____ no____

Name of Parent/Guardian: ______________________________

Signature: ________________________________ Date: _________________

****

Student Consent Form

Workshop to Classroom Research Project
Researcher: Paul Williams

I agree to participate in this research project as indicated below:

Complete surveys: yes ____ no____
Participate in interview: yes ____ no____

Name of Student: ______________________________

Signature: ________________________________ Date: _________________

Appendix E

Student Skill and Knowledge Survey

Hand-held Graphing and Data-Gathering Technology
Student Skill & Knowledge Survey

School: ______________ Course & grade: ______________ Date: ____________

Below is a list of things that can be done on or with a graphing calculator. In the first column, please put an **X** beside those things that you can probably do yourself **with a graphing calculator**. In the second column, please put an **S** beside those things that you did, or saw someone else do, in any of your science classes **with a graphing calculator**. If you don't understand what the item means, leave the item and move on to the next. If you have any comments about graphing calculator technology in science, please use the back of this page. Thank you for your input. Please note: your participation is voluntary!

	I can do	Science	
1.	______	______	Perform basic calculations with the calculator
2.	______	______	Graph a given function (equation)
3.	______	______	Adjust the window (scales) of a graph
4.	______	______	Adjust or correct mode and format settings
5.	______	______	Create "friendly windows"
6.	______	______	Trace to find values on a graph
7.	______	______	Calculate intercepts, zeros (solutions) on a function graph
8.	______	______	Determine the slope at some point on a function graph
9.	______	______	Create a table of values from an equation
10.	______	______	Enter data into lists
11.	______	______	Plot list data as a scatter-plot
12.	______	______	Plot list data as a histogram (bar graph)
13.	______	______	Transfer information from one calculator to another (link)
14.	______	______	Save lists with names for later use
15.	______	______	Modify lists
16.	______	______	Use formulae to manipulate or calculate lists
17.	______	______	Do basic statistics on data lists (e.g. find a mean or median)
18.	______	______	Find a "best-fit" equation
19.	______	______	Graph a best-fit equation on top of actual data plots
20.	______	______	Manage calculator memory
21.	______	______	Use variables and constants
22.	______	______	Use calculator menus
23.	______	______	Run a program from the calculator
24.	______	______	Write a simple program for the calculator
25.	______	______	Use calculator applications (APPS)
26.	______	______	Connect and operate a CBL or CBR
27.	______	______	Gather data with a single probe (data-gathering or measurement device)
28.	______	______	Customize data-gathering process; change data-gathering mode
29.	______	______	Use multiple probes to gather data simultaneously
30.	______	______	Follow a pre-designed procedure to do an experiment
31.	______	______	Customize a data-gathering experiment
32.	______	______	Create or design a data-gathering experiment
33.	______	______	Download programs or APPS to your calculator
34.	______	______	Transfer data from calculator to computer spreadsheet
35.	______	______	Transfer data from computer spreadsheet or internet to calculator

Appendix F

Teacher Interview Protocol

Date: ________ Time: ________ 45-60 minute interview

Teacher Name: ______________

1. What science courses do you teach?
2. In which of these courses are you using graphing calculator technology?
3. How many students are in these classes?
4. How do you think size of the class affects how you use the technology in class?
5. Let's talk a little about equipment issues. What probes or tools related to this technology have you used?
6. Can you briefly tell or show me how you used them in class?
7. To the best of your recollection, please list all the ways you used any of this equipment in any way related to your science class.
8. Do you have any particular issues, concerns, or praise about the equipment you use in your science class?
9. Do you think your students know why these tools were used?
10. Why did you choose to use them? Examples?
11. Do you think that the use was a success? Please explain.
    a. Why or why not?
    b. Was the intended use important for success?
    c. Were there unintended successes?
    d. What were the drawbacks you considered or pitfalls you discovered?
12. Was any part of this technology use new to you?
    a. What was new or where did you use this before?
    b. How did previous experience compare to this?
13. Was any part of this technology use new to your students?
    a. How did they react?
14. How difficult has it been for you to learn to use the technology to the level you needed to implement it in your class?
    a. What made it difficult or what made it easy?
15. How difficult was it for your students in general to learn to use the technology?
    a. What were some of the issues for students learning the technology?
16. How much time did you spend with your students in class so they could learn the technology before it could be used as you intended?
    a. How effective was that time spent?
    b. Was the final result worth the time and effort? Explain.
    c. How would you improve the process?
17. Were you or your students able to do or learn anything using the technology that you might not have done or learned in some other way? Examples?

18. Do you personally like using this technology?
    a. What do you like? Why?
    b. What do you dislike? Why?
19. What about your students? Do they generally like or dislike the technology?
    a. Evidence?
    b. Examples and anecdotes?
20. In your opinion, what are some of the best things about using this technology in class?
21. What are some of the drawbacks?
22. Next time you teach this class, will you use the technology again?
    a. What will you do differently?
    b. What will you do the same?
    c. What will you add or delete?
23. Please identify some issues around the use of this technology in your class and in your school.
24. Any other comments, ideas, thoughts, suggestions, or questions?

Thank You Very Much.

Appendix G

Student Focus Group Protocol

Date: _________ 45 minute maximum

Introduction, welcome and ground rules:

- Thank you for participating in your lunch break.
- Voluntary participation. You may leave at any time.
- Confidence assured. No names will be used, only summary of data.
- This is not an evaluation of anyone, student or staff. Only want opinions on issues related to using technology in science class.
- One person talk at a time; everyone's opinions will be heard.
- Please eat pizza, drink pop, and clean up after.

1. What science class are you in this term that uses this technology?
2. Can you identify any of this equipment?
    a. What does it do?
    b. How did you use it in science?
3. What did you like about using this equipment? Examples?
4. What did you dislike about using this equipment? Examples?
5. How difficult was it to learn how to use the equipment?
    a. How long did it take?
    b. What was the hardest part to learn?
    c. Did some students just not get it?
6. Did the technology help you with your learning in any way? How?
7. Did the technology make it harder for you in class in any way? How?
8. Would you like to use the technology more or less than you used it? Explain.
9. If you were to advise a friend on taking this course from a teacher who used the technology or from one who did not, what would your advice be? Why?
10. General comments on learning and using this technology?

Thank you for your participation!
Here is my business card. If you have any other comments you would like to add, please e-mail or telephone me.

Appendix H

Teacher Skill Survey Result Summary

All Pre	Teacher post	Average final	Differences in Averages post - pre	final - pre	final - post	item #
4.00	4.00	4.00	0.00	0.00	0.00	1
3.00	3.88	3.38	0.88	0.38	-0.50	2
2.75	3.88	3.75	1.13	1.00	-0.13	3
2.50	3.75	3.50	1.25	1.00	-0.25	4
2.38	3.63	3.50	1.25	1.13	-0.13	5
0.25	2.88	3.00	2.63	2.75	0.13	6
2.38	3.50	3.13	1.13	0.75	-0.38	7
2.13	3.25	3.13	1.13	1.00	-0.13	8
1.75	3.63	2.88	1.88	1.13	-0.75	9
1.88	3.13	2.88	1.25	1.00	-0.25	10
2.63	4.00	3.75	1.38	1.13	-0.25	11
2.13	4.00	3.71	1.88	1.59	-0.29	12
2.00	3.50	3.25	1.50	1.25	-0.25	13
3.50	4.00	3.88	0.50	0.38	-0.13	14
0.88	4.00	3.63	3.13	2.75	-0.38	15
1.25	3.63	3.00	2.38	1.75	-0.63	16
1.50	4.00	3.63	2.50	2.13	-0.38	17
2.00	3.88	3.50	1.88	1.50	-0.38	18
1.63	3.50	3.00	1.88	1.38	-0.50	19
1.50	3.75	3.63	2.25	2.13	-0.13	20
1.75	3.88	3.50	2.13	1.75	-0.38	21
1.63	3.63	2.88	2.00	1.25	-0.75	22
1.63	3.25	3.00	1.63	1.38	-0.25	23
0.88	2.25	1.38	1.38	0.50	-0.88	24
2.50	3.63	3.25	1.13	0.75	-0.38	25
2.75	3.63	3.75	0.88	1.00	0.13	26
1.25	1.38	1.38	0.13	0.13	0.00	27
1.00	1.13	1.25	0.13	0.25	0.13	28
2.63	3.88	3.75	1.25	1.13	-0.13	29
2.50	4.00	3.88	1.50	1.38	-0.13	30
2.50	4.00	3.88	1.50	1.38	-0.13	31
1.63	4.00	3.63	2.38	2.00	-0.38	32
1.50	4.00	3.13	2.50	1.63	-0.88	33
1.38	3.88	3.38	2.50	2.00	-0.50	34
0.88	4.00	3.38	3.13	2.50	-0.63	35
2.50	4.00	3.88	1.50	1.38	-0.13	36
1.63	3.50	3.25	1.88	1.63	-0.25	37
1.75	3.63	3.25	1.88	1.50	-0.38	38
2.75	4.00	3.38	1.25	0.63	-0.63	39
3.13	3.38	3.50	0.25	0.38	0.13	40
1.13	2.50	2.38	1.38	1.25	-0.13	41
1.00	2.38	2.13	1.38	1.13	-0.25	42
1.00	1.88	2.00	0.88	1.00	0.13	43
1.94	3.48	3.19	1.54	1.25	-0.29	Total Average

Highlighted values represent reduction in average score for that item.

Appendix I

Teacher Skill Survey Details

Hand-held Graphing and Data-Gathering Technology
Teacher Skill & Knowledge Survey

Graphing Calculator Functionality:

		Pre-institute
1.	Do a mathematical calculation	0 1 2 3 4
2.	Plot a graph of a given function (equation)	0 1 2 3 4
3.	Adjust the window (scales) of a graph	0 1 2 3 4
4.	Modify the graph appearance or display settings	0 1 2 3 4
5.	Adjust or correct mode and format settings	0 1 2 3 4
6.	Create "friendly windows"	0 1 2 3 4
7.	Trace intercepts, zeros (solutions) and interpolate from a graph	0 1 2 3 4
8.	Calculate intercepts, zeros (solutions) and interpolate values from a graph	0 1 2 3 4
9.	Determine the slope at some point on a graph	0 1 2 3 4
10.	Create a table of values from an equation	0 1 2 3 4
11.	Enter data into lists	0 1 2 3 4
12.	Plot list data as a scatter-plot	0 1 2 3 4
13.	Plot list data as a histogram (bar graph)	0 1 2 3 4
14.	Transfer information from one calculator to another (link)	0 1 2 3 4
15.	Move data between lists	0 1 2 3 4
16.	Save lists with names for later use	0 1 2 3 4
17.	Modify lists	0 1 2 3 4
18.	Use formulae to manipulate or calculate lists	0 1 2 3 4
19.	Do basic statistics on data lists	0 1 2 3 4
20.	Use curve fitting techniques to determine data best-fit models (regression)	0 1 2 3 4
21.	Graph a best-fit curve to compare to actual data plots	0 1 2 3 4
22.	Manage calculator memory	0 1 2 3 4
23.	Use variables and constants	0 1 2 3 4
24.	Create and store text and pictures	0 1 2 3 4
25.	Use calculator menus	0 1 2 3 4
26.	Run a program from the calculator	0 1 2 3 4
27.	Write a simple program for the calculator	0 1 2 3 4
28.	Design, write and edit programs to extend the use of the calculator	0 1 2 3 4
29.	Use calculator applications (APPS)	0 1 2 3 4

Data-Gathering and Connectivity Capabilities:

30.	Connect and operate a CBL or CBR	0 1 2 3 4
31.	Gather data with a single probe (data-gathering or measurement device)	0 1 2 3 4
32.	Customize data-gathering process; change data-gathering mode	0 1 2 3 4
33.	Customize probe selection	0 1 2 3 4
34.	Automate data-gathering	0 1 2 3 4
35.	Use multiple probes to gather data simultaneously	0 1 2 3 4
36.	Follow a pre-designed procedure to do an experiment	0 1 2 3 4
37.	Customize a data-gathering experiment	0 1 2 3 4
38.	Create or design a data-gathering experiment	0 1 2 3 4
39.	Connect my calculator to my computer	0 1 2 3 4
40.	Download programs or APPS to my calculator	0 1 2 3 4
41.	Transfer data from calculator to computer spreadsheet	0 1 2 3 4
42.	Transfer data from computer spreadsheet to calculator	0 1 2 3 4
43.	Retrieve data from internet lists to calculator lists	0 1 2 3 4

Hand-held Graphing and Data-Gathering Technology
Teacher Skill & Knowledge Survey

Graphing Calculator Functionality:	**Post-institute**
1. Do a mathematical calculation	0 1 2 3 4
2. Plot a graph of a given function (equation)	0 1 2 3 4
3. Adjust the window (scales) of a graph	0 1 2 3 4
4. Modify the graph appearance or display settings	0 1 2 3 4
5. Adjust or correct mode and format settings	0 1 2 3 4
6. Create "friendly windows"	0 1 2 3 4
7. Trace intercepts, zeros (solutions) and interpolate from a graph	0 1 2 3 4
8. Calculate intercepts, zeros (solutions) and interpolate values from a graph	0 1 2 3 4
9. Determine the slope at some point on a graph	0 1 2 3 4
10. Create a table of values from an equation	0 1 2 3 4
11. Enter data into lists	0 1 2 3 4
12. Plot list data as a scatter-plot	0 1 2 3 4
13. Plot list data as a histogram (bar graph)	0 1 2 3 4
14. Transfer information from one calculator to another (link)	0 1 2 3 4
15. Move data between lists	0 1 2 3 4
16. Save lists with names for later use	0 1 2 3 4
17. Modify lists	0 1 2 3 4
18. Use formulae to manipulate or calculate lists	0 1 2 3 4
19. Do basic statistics on data lists	0 1 2 3 4
20. Use curve fitting techniques to determine data best-fit models (regression)	0 1 2 3 4
21. Graph a best-fit curve to compare to actual data plots	0 1 2 3 4
22. Manage calculator memory	0 1 2 3 4
23. Use variables and constants	0 1 2 3 4
24. Create and store text and pictures	0 1 2 3 4
25. Use calculator menus	0 1 2 3 4
26. Run a program from the calculator	0 1 2 3 4
27. Write a simple program for the calculator	0 1 2 3 4
28. Design, write and edit programs to extend the use of the calculator	0 1 2 3 4
29. Use calculator applications (APPS)	0 1 2 3 4

Data-Gathering and Connectivity Capabilities:	
30. Connect and operate a CBL or CBR	0 1 2 3 4
31. Gather data with a single probe (data-gathering or measurement device)	0 1 2 3 4
32. Customize data-gathering process; change data-gathering mode	0 1 2 3 4
33. Customize probe selection	0 1 2 3 4
34. Automate data-gathering	0 1 2 3 4
35. Use multiple probes to gather data simultaneously	0 1 2 3 4
36. Follow a pre-designed procedure to do an experiment	0 1 2 3 4
37. Customize a data-gathering experiment	0 1 2 3 4
38. Create or design a data-gathering experiment	0 1 2 3 4
39. Connect my calculator to my computer	0 1 2 3 4
40. Download programs or APPS to my calculator	0 1 2 3 4
41. Transfer data from calculator to computer spreadsheet	0 1 2 3 4
42. Transfer data from computer spreadsheet to calculator	0 1 2 3 4
43. Retrieve data from internet lists to calculator lists	0 1 2 3 4

Hand-held Graphing and Data-Gathering Technology
Teacher Skill & Knowledge Survey

Graphing Calculator Functionality:

Final

1.	Do a mathematical calculation	0	1	2	3	4
2.	Plot a graph of a given function (equation)	0	1	2	3	4
3.	Adjust the window (scales) of a graph...	0	1	2	3	4
4.	Modify the graph appearance or display settings	0	1	2	3	4
5.	Adjust or correct mode and format settings	0	1	2	3	4
6.	Create "friendly windows"...	0	1	2	3	4
7.	Trace intercepts, zeros (solutions) and interpolate from a graph	0	1	2	3	4
8.	Calculate intercepts, zeros (solutions) and interpolate values from a graph	0	1	2	3	4
9.	Determine the slope at some point on a graph.....................................	0	1	2	3	4
10.	Create a table of values from an equation	0	1	2	3	4
11.	Enter data into lists	0	1	2	3	4
12.	Plot list data as a scatter-plot...	0	1	2	3	4
13.	Plot list data as a histogram (bar graph)	0	1	2	3	4
14.	Transfer information from one calculator to another (link)	0	1	2	3	4
15.	Move data between lists..	0	1	2	3	4
16.	Save lists with names for later use	0	1	2	3	4
17.	Modify lists	0	1	2	3	4
18.	Use formulae to manipulate or calculate lists..	0	1	2	3	4
19.	Do basic statistics on data lists	0	1	2	3	4
20.	Use curve fitting techniques to determine data best-fit models (regression)	0	1	2	3	4
21.	Graph a best-fit curve to compare to actual data plots..............................	0	1	2	3	4
22.	Manage calculator memory	0	1	2	3	4
23.	Use variables and constants	0	1	2	3	4
24.	Create and store text and pictures..	0	1	2	3	4
25.	Use calculator menus	0	1	2	3	4
26.	Run a program from the calculator	0	1	2	3	4
27.	Write a simple program for the calculator..	0	1	2	3	4
28.	Design, write and edit programs to extend the use of the calculator	0	1	2	3	4
29.	Use calculator applications (APPS)	0	1	2	3	4

Data-Gathering and Connectivity Capabilities:

30.	Connect and operate a CBL or CBR..	0	1	2	3	4
31.	Gather data with a single probe (data-gathering or measurement device)	0	1	2	3	4
32.	Customize data-gathering process; change data-gathering mode	0	1	2	3	4
33.	Customize probe selection..	0	1	2	3	4
34.	Automate data-gathering	0	1	2	3	4
35.	Use multiple probes to gather data simultaneously	0	1	2	3	4
36.	Follow a pre-designed procedure to do an experiment.............................	0	1	2	3	4
37.	Customize a data-gathering experiment	0	1	2	3	4
38.	Create or design a data-gathering experiment	0	1	2	3	4
39.	Connect my calculator to my computer..	0	1	2	3	4
40.	Download programs or APPS to my calculator	0	1	2	3	4
41.	Transfer data from calculator to computer spreadsheet	0	1	2	3	4
42.	Transfer data from computer spreadsheet to calculator.............................	0	1	2	3	4
43.	Retrieve data from internet lists to calculator lists	0	1	2	3	4

Appendix J
PCSI Evaluation Survey Results

		#1	2	3	4	5	6	7	8	9	10	**mean**	StDev		
Q1															**Handout materials**
	1.1	5	5	5	4	4	5	5	5	5	4	**4.70**	1.18		organization
	1.2	5	5	5	5	5	5	5	5	5	4	**4.90**	1.16		content quality
	1.3	5	5	5	5	5	5	5	5	5	5	**5.00**	1.12		content quantity
	1.4	5	5	5	4	5	5	5	5	5	4	**4.80**	1.10		readability
	1.5	5	5	5	4	4	5	5	5	5	5	**4.80**	1.07		layout
Q2															**Scheduling of workshop days**
	2.1	2.5	2	4	4	4	3	5	3	3	3	**3.35**	0.92		timing
	2.2	3	4	5	4	4	3	5	3	3	3	**3.70**	0.90		dates
	2.3	5	4	5	4	4	4	5	5	5	4	**4.50**	0.83		length of institute
	2.4	5	5	5	5	4	5	5	5	4	4	**4.70**	0.83		topic/activity organization
Q3	3.1	5	5	5	5	5	5	5	5	4	5	**4.90**	0.62		**Activities offered**
Q4															**Venues**
	4.1	5	5	5	5	4	4	5	5	5	4	**4.70**	0.49		Red Deer College
	4.2	6	5	3	5	4	4	5	5	5	4	**4.60**	0.81		St. Francis Xavier
	4.3	5	5	5	5	5	4	5	5	5	4	**4.80**	0.43		Breaks & refreshments
	4.4	5	5	5	5	5	4	5	5	5	5	**4.90**	0.34		meals
Q5	5.1	5	5	5	4	5	5	5	5	4	4	**4.70**	0.47		**Debriefing or Issue discussions**
Q6	6.1	4	4	4	4	4	4	4	4	3	3	**3.80**	0.80		**Homework & reflections**
Q7														**	**Facilitator/Instructor**
	7.1	5	5	5	5	5	5	5	5	5	4	**4.90**	0.73	*	effectiveness
	7.2	5	5	5	5	4	5	5	5	5	5	**4.90**	0.76		knowledge
	7.3	5	5	5	5	5	5	5	5	5	4	**4.90**	0.78	*	support provided
Q8	8.1	5	5	5	5	4	5	5	5	5	4	**4.80**	1.07		Available equipment
Q9															**Sessions:**
	9.1	5	5	5	5	3	5	5	5	5	4	**4.70**	1.47		hardware instruction & practice
	9.2	5	5	5	5	3	5	4	5	5	4	**4.60**	1.54		data plotting instruction & practice
	9.3	5	4	4	5	3	5	4	5	4	5	**4.40**	1.62		analysis instruction & practice
	9.4	5	5	5	5	4	5	5	5	4	5	**4.80**	1.44	*	science connections, issue discussions
	9.5	5	3		3	3	2	3	4	4	4	**3.44**	2.09		authentic assessment
	9.6	5	3	4	3	4	3	5	5	4	4	**4.00**	1.86		outdoors
	9.7	4	4		3	3	3	5	4	4	2	**3.56**	2.11		TI Connect
	9.8	5	3		3	3	1		3	4	2	**3.00**	2.53		TI Interactive
	9.9	5	5	5	5	5	5	5	5	5	5	**5.00**	1.48	**	Individual presentations
	9.10	5	5	5	5	5	5	5	5	5	4	**4.90**	1.30		Technology issues discussions
	mean	*4.82*	*4.53*	*4.78*	*4.47*	*4.17*	*4.30*	*4.83*	*4.70*	*4.50*	*4.03*	**4.51**			

Scoring:
1 = of no use or interest; very poor
2 = of little use or interest; poor
3 = not sure, neutral, or no opinion
4 = useful or interesting; good
5 = very useful or very interesting; very good

* Some write-in scores of 6 to 10
** extra comments: outstanding, excellent

Appendix K

Student Survey Results

Class averages of % positive response Initial survey Item # I Can Do												Total Average
1	100	100	100	91	100	100	97	97	100	100	100	99
2	97	100	92	86	79	100	100	91	100	96	100	95
3	97	100	92	68	74	100	97	97	100	91	100	92
4	93	85	80	68	74	83	77	79	81	91	81	81
5	20	11	4	23	5	40	30	39	22	61	25	26
6	93	96	80	77	47	87	100	91	93	96	94	87
7	90	100	76	77	37	100	100	91	93	96	100	87
8	73	93	68	55	63	73	67	67	70	83	88	73
9	83	89	80	68	53	90	87	85	100	96	81	83
10	73	67	68	68	47	83	63	79	89	87	88	74
11	50	59	32	41	53	70	47	55	74	78	69	57
12	43	44	20	14	21	33	23	36	59	70	56	38
13	73	37	40	45	42	27	50	36	52	61	69	48
14	20	22	24	14	16	23	23	21	26	57	44	26
15	43	33	16	27	21	47	30	36	44	48	50	36
16	37	44	24	36	16	23	37	30	26	48	44	33
17	43	44	40	41	5	57	60	45	52	57	75	47
18	50	59	40	32	32	43	27	58	52	70	63	48
19	40	37	28	41	26	33	17	42	48	52	31	36
20	73	56	52	45	37	30	70	45	63	78	63	56
21	83	74	68	50	47	57	73	55	81	96	81	70
22	87	81	68	59	42	70	83	79	93	78	94	76
23	77	56	56	64	68	60	73	76	74	78	88	70
24	30	11	12	14	11	13	13	12	19	35	25	18
25	53	41	56	59	47	57	50	70	74	70	63	58
26	47	15	28	32	32	17	30	45	63	70	69	41
27	10	15	24	18	16	17	30	45	70	74	63	35
28	7	22	16	18	0	3	13	21	37	57	31	21
29	7	11	8	14	0	3	6.7	27	19	48	31	16
30	20	26	40	55	37	40	47	33	63	74	69	46
31	7	4	12	18	0	3	17	15	26	43	31	16
32	3	4	4	27	0	17	17	3	15	39	13	13
33	67	19	32	32	42	33	33	52	63	57	50	44
34	10	11	20	45	21	20	3.3	12	15	22	31	19
35	10	7	20	18	5	13	0	12	19	22	25	14
total	52	48	43	44	35	48	48	51	59	68	62	51

Class averages

of % positive response

Final survey

Item # I Can Do												Total Average	Final - initial Difference in %
1	100	100	100	94	100	100	100	100	100	96	100	99	0.5
2	88	100	89	94	100	100	100	95	100	96	100	97	2.1
3	92	100	95	94	95	100	96	100	100	92	100	97	4.4
4	92	96	95	94	89	100	89	100	95	79	100	94	12.5
5	42	31	42	28	37	67	32	45	25	50	54	41	15.7
6	92	88	89	94	95	96	96	100	95	92	100	94	7.7
7	92	100	79	94	68	96	100	100	100	92	100	93	5.7
8	88	88	84	72	63	88	75	82	95	75	62	79	6.7
9	85	92	79	89	84	92	82	95	95	79	85	87	4.1
10	85	85	84	89	89	100	68	86	85	83	92	86	12.2
11	77	81	68	89	84	88	71	77	70	75	77	78	20.9
12	65	42	42	61	53	42	43	50	50	79	69	54	16.0
13	81	58	68	89	84	67	61	59	70	71	69	71	22.2
14	35	12	47	72	58	58	29	45	25	50	54	44	17.7
15	58	46	47	61	74	63	32	55	35	63	46	53	16.6
16	58	38	42	39	68	38	21	41	40	58	46	45	11.3
17	62	69	42	72	63	54	46	64	65	54	77	61	13.6
18	73	46	53	78	74	58	43	73	55	75	77	64	16.4
19	58	27	42	78	58	50	36	50	60	63	54	52	16.2
20	77	54	74	72	79	63	86	64	60	79	62	70	14.2
21	73	81	58	83	79	71	75	68	70	71	77	73	3.6
22	81	96	84	72	84	71	82	91	80	88	77	82	6.5
23	85	65	74	89	89	79	93	82	85	79	69	81	10.9
24	19	0	21	11	21	29	32	14	25	46	31	23	5.0
25	77	65	58	72	79	83	82	86	80	67	77	75	17.1
26	85	81	47	89	89	75	89	86	90	88	100	84	43.0
27	88	77	47	72	84	79	89	91	90	88	100	82	47.7
28	77	54	21	44	53	29	68	59	60	63	69	54	33.7
29	35	27	21	28	26	25	32	27	20	71	62	34	18.1
30	81	69	58	83	95	83	86	91	85	79	92	82	36.3
31	77	31	16	39	21	25	50	36	40	63	31	39	22.9
32	50	12	21	33	26	17	36	32	30	50	31	31	17.8
33	73	65	42	83	79	63	75	59	60	54	69	66	22.2
34	42	23	16	72	47	67	29	32	15	38	54	39	20.3
35	31	12	11	44	42	17	7.1	14	5	29	46	23	9.6
total	71	60	56	71	69	67	64	67	64	71	72	66	15.8

Class averages

of % positive response

Initial survey

Item # / I Saw in Science												Total Average
1	67	30	52	45	5	20	23	82	67	57	69	47
2	67	26	32	45	0	17	20	73	74	61	75	44
3	63	26	36	50	0	17	23	79	74	61	69	45
4	63	26	36	45	0	23	37	70	56	57	63	43
5	27	44	32	23	0	20	17	30	33	48	25	27
6	63	19	28	41	0	13	20	70	70	52	63	40
7	53	22	32	41	0	13	20	58	78	52	56	39
8	53	26	24	45	0	27	40	61	78	48	56	42
9	60	22	28	45	0	17	33	64	67	57	44	40
10	53	26	36	32	5	23	40	58	70	48	50	40
11	50	30	40	59	5	27	57	52	56	52	56	44
12	37	26	32	36	0	30	57	30	44	48	50	35
13	67	44	36	55	16	40	43	73	56	70	44	49
14	37	30	24	36	0	50	43	30	48	30	50	34
15	33	30	20	36	0	37	27	45	56	39	38	33
16	33	41	24	27	0	47	37	30	41	26	25	30
17	40	22	16	27	0	33	23	39	56	35	56	32
18	47	26	12	50	11	33	40	55	67	43	56	40
19	33	26	12	41	5	40	37	36	63	48	50	36
20	50	11	16	45	0	47	23	52	59	48	56	37
21	50	11	12	27	0	20	37	36	56	52	56	32
22	53	19	24	23	0	20	23	52	70	57	63	37
23	53	26	36	32	11	23	37	64	67	52	69	43
24	33	30	20	45	5	20	43	21	37	35	19	28
25	57	30	24	36	5	27	40	61	56	48	38	38
26	57	44	16	50	11	37	30	73	63	48	56	44
27	27	37	32	45	5	33	57	48	59	48	44	40
28	13	41	24	27	0	17	47	21	52	43	38	29
29	13	33	16	27	0	20	30	24	48	39	38	26
30	20	30	12	36	0	13	37	27	59	48	56	31
31	17	33	20	18	0	17	30	15	48	26	44	24
32	10	37	20	23	0	7	27	12	37	30	25	21
33	50	33	32	45	16	30	50	58	48	52	50	42
34	27	41	20	36	11	20	27	24	33	52	44	30
35	27	37	16	32	11	20	33	15	30	39	31	26
total	43	30	25	38	3	26	34	47	56	47	49	36

Class averages
of % positive response
Final survey

Item # I Saw in Science												Total Average	Final - initial Difference in %
1	58	62	32	44	47	25	54	36	50	67	46	47	0.4
2	62	54	32	50	47	13	50	41	45	58	54	46	1.4
3	69	58	21	50	53	13	54	36	45	58	46	46	0.4
4	62	58	21	50	47	13	57	36	40	54	46	44	0.8
5	42	27	37	33	26	21	32	27	20	33	23	29	2.1
6	69	62	26	50	47	13	50	36	45	58	38	45	5.1
7	54	50	21	50	42	13	50	36	35	63	38	41	2.4
8	50	58	37	61	53	29	50	36	30	42	46	45	3.1
9	54	58	32	50	53	17	61	32	30	54	54	45	5.2
10	54	46	32	56	47	25	50	36	40	58	62	46	5.8
11	46	46	32	50	53	33	50	23	30	46	54	42	-1.9
12	38	42	32	50	16	13	50	23	40	42	46	36	0.1
13	65	54	63	50	47	46	61	50	45	58	54	54	4.6
14	23	31	26	61	42	50	43	41	30	42	62	41	6.5
15	38	38	26	50	37	25	36	18	30	50	54	37	3.9
16	31	23	21	56	32	33	29	27	25	50	54	35	4.5
17	38	38	26	44	37	21	50	45	30	50	46	39	7.2
18	46	38	21	67	42	21	50	32	45	54	38	41	1.4
19	31	27	21	67	53	21	43	36	35	42	38	38	2.0
20	65	38	26	33	47	25	43	36	40	46	54	41	4.3
21	50	50	21	39	53	21	36	27	35	50	54	40	7.1
22	50	50	16	22	47	8	57	41	40	54	62	41	4.1
23	69	50	42	44	53	29	43	41	55	50	54	48	5.6
24	19	15	16	44	47	13	39	59	25	33	31	31	3.0
25	58	38	37	50	47	33	39	36	40	42	38	42	3.6
26	73	62	42	56	53	58	61	41	40	58	54	54	10.3
27	69	65	37	50	58	42	46	45	45	46	62	51	11.8
28	54	46	21	17	32	17	43	32	50	54	31	36	6.6
29	58	42	26	56	26	17	43	45	25	63	23	39	12.3
30	73	46	53	44	47	33	43	41	55	38	38	47	15.7
31	54	35	26	50	42	17	43	41	45	54	38	40	16.1
32	35	35	11	39	26	13	54	36	40	58	31	34	13.5
33	65	50	37	39	53	50	54	41	50	58	54	50	7.8
34	73	54	26	50	37	46	68	59	35	71	62	53	22.3
35	62	35	26	39	42	38	43	64	25	46	46	42	15.8
total	53	45	29	47	44	26	48	38	38	51	47	42	6.1

Appendix L

Recommended Beginning Equipment List

Suggested Equipment Needs
to Begin Implementing Graphing Calculator Data Collection

1. ViewScreen™ overhead palette with a TI 83SE calculator.

2. Set of CBL-2™ (Calculator Based Laboratory, a sensor-calculator interface):
   - minimum of 1 CBL-2™ for every three students.
   - 1 extra CBL-2™ for demonstration purposes.
   - Note: the CBL-2™ comes with three probes:
     i. Temperature.
     ii. Voltage.
     iii. Light intensity.

3. Power adapters for CBL-2™ use. Saves on battery costs and dead battery problems.

4. Set of CBR™ (Calculator Based Ranger)
   - The CBR™ measures distance with ultrasound echo ranging.
   - The CBR™ has an internal program (Ranger) that allows the user to record distance, velocity, and acceleration; and plot time graphs of each.
   - There are several other useful features in the Ranger program such as:
     i. Graph Match
     ii. Ball Bounce

5. Force probes for Science 10 and Physics

6. pH probes for Chemistry

The following are some of the more useful probes from over two dozen that are available:

7. Gas pressure sensors for all sciences

8. Photogates for Physics.

9. EKG and Heart rate monitor: one for Biology demonstrations.

10. Force Plate: one for Physics demonstrations.

11. Many other probes are useful for demonstrations or classroom use. Grow your collection.

Appendix M

Student Introduction Lesson Outline

A Skeleton Outline to Introduce Students to Graphing Calculator Data-Gathering

1. Inform students of basic calculator skills they should have. These should be worked on during the first part of the school term. This includes:
    - Basic calculations with brackets, exponents and multiple steps.
    - Setting calculator modes, formats, and windows appropriately.
    - Entering data into lists, editing lists, and managing lists.
    - Creating appropriate scatter plots (graphs) from lists.
    - Using the calculator's regression functions to determine a curve of best fit.

2. Provide students with hands-on exposure to data-gathering hardware including:
    - CBL-2™
    - A variety of probes or sensors such as:
        a. Temperature probe
        b. CBR™
        c. Force sensor

3. Show students how to download appropriate software to their TI 83^{+}
    - DataMate APP (application) linked from the CBL-2™
    - Ranger program linked from the CBR™

4. Demonstrate, with students following along, how to connect a simple probe such as the temperature probe and set up a basic time graph through DataMate.

5. Students gather data and explore the DataMate options for data display and analysis.

6. Explore DataMate modes of data-gathering such as:
    - Various time settings for time graphs
    - Events with entry

7. Close DataMate. Find data in lists, name lists, and plot suitable graphs from the named lists.

8. Demonstrate how to download data from the calculator to a computer and print off graphs or data tables.

9. Encourage students to explore the use of the single probe in gathering data.