In the Shoes of a Student: Professional Development in a Classroom Context

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Abstract

While professional development for teachers exists in many forms, no particular one emerges as the best way to facilitate change in classroom practices. Evidence from the Elementary Science and Technology project suggests that teachers implementing a new curriculum require a variety of professional development experiences. Also emerging is the importance of developing and sustaining school-university partnerships and professional communities of practice.

This paper describes the results from a programme of research in which two faculty instructors taught Grade 6 students a science or technology unit, while six teachers worked alongside the students to complete the same unit. The results of the study are being used to address two research questions: (a) to what extent does in-service given in a classroom context help teachers to acquire a pedagogy for elementary technology or elementary science and (b) to what extent does in-service given in a classroom context help teachers to acquire subject knowledge in elementary technology or elementary science?

Introduction

Professional development (PD) for classroom teachers currently exists in many forms. While research points to several crucial elements in effective PD, as yet no one form emerges as the best way. Recent research suggests the importance of developing and sustaining school-university partnerships and professional communities of practice in the teaching profession (National Research Council, 1999). What is not so clear is how teachers learn in and through PD experiences and if and how they apply their learning. Empirical research that illustrates how teachers experience and describe their PD learning may provide another link in understanding and fostering the increasing expectations to document the nature of professional growth.

The next section of this paper provides an overview of the literature describing crucial elements in effective PD for teachers. This is followed by a brief description of the Elementary Science and Technology (EST) project and its approach to teaching science and technology and the PD provided to teachers in response to their emerging requirements while writing curriculum materials. Finally, the paper reports some results of a study designed to investigate the effectiveness of a PD experience given in a classroom in which Grade 6 students completed a technology unit or a science unit. The foci for the teachers were the pedagogy employed by two faculty instructors and the knowledge and skills embedded in the activities. The study addressed two research questions: (a) to what extent does in-service given in a classroom context help teachers acquire a pedagogy for elementary technology and elementary science and (b) to what extent does in-service given in a classroom context help teachers acquire subject knowledge in elementary technology and elementary science?

Professional development for teachers

Single-event PD activities (e.g. daylong sessions), what Shanker (1996) refers to as 'one-shot workshops' and what Little (1993) calls an 'implementation-of-innovations' model, are the most frequent form of PD for teachers. While such PD may be useful for introducing ideas, it does not facilitate change or noticeable improvements in classroom and professional practices (Osterman and Kottkamp, 1993). Furthermore, these single-event activities typically assume an inappropriate stance toward teacher change. They present ideas, give tips, provide handouts, project a certainty about the topic and assume that the giving and receiving of public knowledge will lead to behavioural change. According to Little (1993), single-event PD activities 'can, at best, be used to suggest new classroom practices' (p. 156).

Research has identified four crucial elements in effective PD, that is, development that leads to positive change in the classroom. First, PD must provide a challenge to teachers' frames of reference (Carney, 1998). While new professional demands, for example those created by the introduction of a new curriculum, can make teachers receptive to new understandings and practices, they may lack frames for these situations and seek help in structuring new routines. Ball (1996) suggests that PD must challenge teachers to investigate, experiment, consult and consider outcomes: to take a stance of critique and enquiry towards practice. PD must encourage teachers to use an enquiry and problem-solving paradigm that results in their producing new knowledge, rather than a training paradigm that results in their consuming knowledge.

Second, PD must be situated in relevant contexts if teachers are to learn and apply new knowledge (Carney, 1998). Situated cognition and sociocultural context (Brown, Collins and Duguid, 1989; Rogoff, 1994) are basic cognitive principles of constructivist theory. Grossman (1992) argues that this type of learning is important for teachers; they must be able to situate new knowledge and understanding in the specific context of

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classrooms. PD should be based on the participants' interests and needs (Vukelich and Wrenn, 1999) and must be relevant to actual classroom work and to what students need to know and be able to do (Cameron, 1996).

Third, collaborative support from other teachers greatly increases the likelihood that changes in practice will be sustained (Fullan and Stiegelbauer, 1990). Teachers need colleagues with whom to focus on problems of teaching and learning, to work out how to deal with new subject matter and to engage in innovative work aimed at curriculum reform (Olson, 1997; Shanker, 1996). A collaborative approach is based on notions of teachers as colleagues engaged in enquiry about practice (Lieberman and Miller, 1990; Smylie, 1996). Furthermore, since learning is incremental and teachers do not change their practices overnight, PD should be long-range and ongoing (Smylie, 1996). According to Ball (1996), teachers need time to unlearn as much as they learn.

Fourth, PD must provide opportunities for teachers to form 'communities of practice' (Lave and Wenger, 1991) that encourage them to reflect on the content and contexts of their pedagogy. Schön (1987), for example, demonstrated the importance of reflection-in-action and reflection-on-action for the development of professional practice. Louden (1991) argues that reflection is a basic source of learning and change. A collaborative approach is based on notions of teachers as colleagues engaged in enquiry about practice (Lieberman and Miller, 1990).

A simple subject construct model for technology education has been used with some success in initial teacher education (Banks and Barlex, 1999; Banks et al, 2000). The model identifies three areas in which new professional knowledge can be created: subject knowledge, pedagogic knowledge and school knowledge. So the model indicates that teachers should 'know their stuff' (subject knowledge), 'know how to teach their stuff' (pedagogic knowledge) and 'know how to teach their stuff in their school' (school knowledge). This model can be used to set an agenda for PD that acknowledges the four crucial elements for effective PD described above.

The Elementary Science and Technology Partnership

The Elementary Science and Technology (EST) Partnership involves a collaboration between the Faculty of Education at Queen's University and two local school boards. A three-year project, it has as one of its primary goals the provision of PD for a group of teachers implementing a new Grade 1-8 science and technology curriculum (Ministry of Education and Training, 1998). This curriculum poses significant challenges for elementary school teachers about how to teach the subjects, how to assess students' learning in the subjects and how to use the document to plan units of work (Barlex et al, 2000; Welch et al, 2000). This is especially so for those teachers who do not have a science or technology background.

The approach to teaching science and technology developed by the EST Partnership has, at its centre, the concept of a big task (BT). A BT is a significant activity in which students have to use the knowledge, understanding and skill they have been taught in an integrated and holistic way. It forms a focal point in a teaching sequence and enables students to reveal what they have learned through what they can do. For students to be successful in a BT they will need particular and appropriate knowledge, skill and understanding. These are taught through a series of support tasks: short, highly structured and focused activities. The effectiveness of this teaching and learning is evidenced through the quality of response to the BT. This is a development of the capability task/resource task approach developed by the Nuffield Design and Technology Project in England (Barlex, 1995).

In an EST unit that focuses on science, the big task requires students to answer a big question (BQ). Answering a BQ will require students to use knowledge of science processes and concepts to collect, organise and analyse data in order to produce a reasoned argument. Students may use data from their own investigations or from secondary sources. They may present their answers in a variety of ways, for example, in a log book, in a formal report or multimedia presentation and they may work as an individual or member of a small group presentations.

In an EST unit that focuses on technology, the big task is called a design and make activity (DMA). A DMA requires students to intervene in, and make improvements to, the made world by designing something that they themselves can make and then making the product they have designed. Both the product and the processes by which it is conceived, developed and realised are significant in this activity.

The EST project has provided a range of ongoing PD experiences, including practical workshops (in both science and technology), seminars, writing days, tutorials and conversations by telephone and e-mail (Welch, Barlex and Mueller, 2001). In the

practical workshops in both science and technology, teachers completed a unit of work (a big task and its associated support tasks) in order to experience a new pedagogical approach to the subjects and also to gain new subject knowledge. In the seminars teachers were able to put their PD in the context of current educational issues (e.g. assessment, meeting curriculum expectations and the proposed pedagogy). On the writing days teachers worked both collaboratively and individually to plan and develop curriculum units. Tutorials provided each teacher with the opportunity to work one-on-one with a consultant in refining their curriculum unit. E-mail was used to maintain on-going conversations with teachers about their curriculum units as they were written. Conversations by telephone dealt with specific day-to-day problems as they arose.

The next section of this paper describes a six-step programme of research, entitled In-service in context: Learning science and technology with students in elementary classrooms (ISIC), designed to investigate an innovative form of PD and to respond to ongoing concerns of EST teacher partners.

Method

In Step 1 of the ISIC research programme two faculty instructors (the authors) taught a technology unit entitled Will this story surprise you? to a class of 27 Grade 6 students for one school day (Barlex, 2000). The teaching occurred in a large classroom in the school of one of the EST teachers. The design brief for this unit reads as follows: ‘Design and make a pop-up book that will amuse and intrigue a particular reader. The book may be for you or for someone else.’ Prior to tackling this DMA, the students completed eight support tasks to learn a variety of paper engineering techniques, illustration styles and how to write a design specification:

- investigating pop-up books
- exploring a box fold
- exploring a mouth fold
- exploring a slider
- exploring a lift-up flap
- exploring a rotator
- exploring illustration styles
- writing the design specification.

Concurrently, six teachers from the EST project worked alongside the students to complete the same unit.

In Step 2 of the research the same two faculty instructors taught a science unit that required Grade 6 students to answer the following question: Why is it important to classify things? Prior to answering this BQ students completed six support tasks to learn about classification, classification keys and how scientists classify vertebrates and invertebrates:

- why is it important to classify things?
- classifying objects
- classifying living things
- using and creating a word key
- the animal kingdom: vertebrates
- the animal kingdom: invertebrates.

Figure 1: Learning alongside students.

Once again, the six teachers from the EST project worked alongside the students. Both the technology unit and the science unit met the expectations contained in the Ontario Ministry of Education Grade 1-8 Science and Technology Curriculum (Ministry of Education and Training, 1998).

In Steps 3 and 4 of the ISIC research programme the faculty instructors taught the same science and technology units while six non-EST teachers worked alongside a second group of Grade 6 students. Hence, the four steps in the programme of PD afforded 12 teachers (six EST and six non-EST) an opportunity to (a) participate in an approach to teaching science or technology, (b) acquire knowledge, skills and understanding and (c) reflect on issues related to teaching and learning elementary science and technology.

Data was collected in a variety of forms and in three phases at each step of the study. Phase one occurred prior to the unit being taught. A written questionnaire was used to identify (a) teachers’ current knowledge and skills and (b) teachers’ current knowledge about teaching science or technology. Phase two of data collection occurred while the students and teachers were completing the support tasks and the big task. Teachers were asked to record their thoughts about teaching and learning science or technology in a

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prepared field notes booklet. Phase three occurred after the unit had been taught and had two components. First, a second written questionnaire was used to identify (a) teachers' post in-service knowledge and skills and (b) teachers' post in-service knowledge about teaching science or technology. Second, the researchers conducted a focus group interview with the teachers. Data from the first questionnaire and the events of the day guided the nature and structure of the focus group interview. Analysis of the interview data involved thematic analysis and concept analysis (Miles and Hubermann, 1994; Silverman, 1993). Initial coding categories were identified by both teacher educators individually and then compared and checked for consistency before final coding categories were derived.

The remaining sections of this paper focus on insights from teachers participating in the study and how these reveal ways in which the ISIC experience helped them learn and grow as teachers.

Results

Thematic and concept analysis of field notes booklets, questionnaires and focus group interviews reveals a number of common threads of experience and emphasis by teachers. Distinguishing features include: (a) teacher emphasis on the importance of their learning with students for their PD and (b) the unique experience of learning from students.

Teachers' subject knowledge of elementary science and technology

The first section of the pre in-service questionnaire asked teachers to describe their current subject knowledge. On a technology day the questionnaire asked for their knowledge about generating, developing and communicating design ideas, their 2D and 3D modelling skills and their technical knowledge of structures. The majority of teachers reported little or no prior knowledge in these areas. Teachers reported feeling insecure about their lack of knowledge of technology content contained in the curriculum. An exception was one teacher who had taught industrial arts at secondary level and described in detail a high level of competence.

The pre in-service questionnaire completed by teachers on a science day asked for their knowledge of subject matter in the five strands in the elementary science and technology curriculum: life systems, matter, energy and earth and space systems (Ministry of Education and Training, 1998). In addition, teachers were asked to describe their prior knowledge of planning scientific experiments or investigations, conducting scientific experiments or investigations, observing and recording data in science, analyzing scientific data and communicating (disseminating) data. The majority of teachers reported some university level courses in a single science (e.g. biology). Their level of confidence with the subject content ranged from very high (reported by a teacher with an undergraduate degree in science) to very low.

Data from the post in-service questionnaires and the focus group interviews indicated that because the tasks involved quite simple technological knowledge and basic making skills or simple scientific knowledge the teachers were able to focus on teaching strategies and student responses to the tasks. For example, teachers reported that they learned quickly the paper engineering techniques. As one teacher wrote:

> 'At first I was a little disappointed that we were doing paper technology because although I'd never taught that stuff, it's not something that's hard for any of us to learn from a book. But on looking back I think it was actually probably helpful because it allowed me to concentrate on the pedagogy. I wasn't so worried about trying to figure out how to do it myself.' (Teacher 3)

This data suggests that while in-service in context may be a powerful way to introduce teachers to a new area of the curriculum and its associated pedagogy, it may not be an effective method for teaching new subject content.

Teachers' pedagogical knowledge for science and technology education

The second section of the pre in-service questionnaire asked teachers to describe their approach to teaching science and technology and the kinds of experiences they provided for students. EST teachers' responses on the technology days included:

> 'I only taught from prepared purchased units that didn't have an end purpose. Each activity was an entity unto itself – neither rhyme nor reason for why it happened in the unit where it did.' (Teacher 1)

> 'I would find something and think 'this looks like fun' and then dive in. We would all sort of muddle through and hope things would work in the end.' (Teacher 2)

> 'I used to do a lot of board notes and found that I was intimidated by doing a lot of hands-on activities. Those hands-on activities that I did do were usually teacher-led demonstrations at the front of the class.' (Teacher 5)

This data indicates that the big task-support task approach was considerably outside the initial pedagogic range of the teachers concerned.

The responses of non-EST teachers to the question regarding their current approach to teaching technology and the kinds of experiences they provide for students made clear that the majority did not understand the difference between science and technology. As one teacher wrote:

> 'Most of my design ideas centre around designing and conducting experiments. For example, my class is currently working on a paper towel experiment based on using the scientific method and ensuring a fair test.' (Teacher 7)

Several non-EST teachers were equally unclear about the meaning of the term 'technology', making reference to information and communications technology. For example, one teacher reported that she taught 'mainly computer technology ... [and] some technology involved in science projects.' (Teacher 3)

When asked to describe their current approach to teaching science and the kinds of experiences provided for students, both EST and non-EST teachers frequently used the phrase 'hands-on' but did not describe what this meant. Several teachers reported that students were required to complete a lot of note taking and teacher-led experiments. Several teachers reported providing experiences that focus on enquiry and on using the scientific method. One teacher wrote '[I] provided lots of knowledge and activities without tying things together at the end.' (Teacher 2)

Data from the post in-service questionnaires and the focus group interviews at the end of the two technology days indicate that teachers found observing two experienced faculty instructors engage students in making design decisions helpful. They reported it as a powerful way to acquire an understanding of an aspect of teaching and learning in technology education with which they had little or no familiarity. Teachers also reported that the experience was successful in helping them acquire teaching strategies for helping students to realise the making of their designs.

As part of the post in-service questionnaire EST teachers were asked to report on the difference in their learning with students as part of the in-service versus their learning during other EST in-service days held in a Queen's Faculty of Education classroom. Teachers' comments included:

> 'As a learner, I find it much more successful and appropriate to be learning with the kids, rather than just being told how to teach it. I ... feel like this is a much wiser and applicable method of teaching teachers how to teach!' (Teacher 1)

> 'Well, great to ... see what works – what might be changed. Always wonderful to see something done, tried out before you have to do it yourself.' (Teacher 2)

Learning with and learning from students

The unusual opportunity to work alongside students prompted experienced teachers to reflect upon their own learning, children's learning and to examine their teaching practices from new perspectives. Teachers commented on how they learned and gained a unique insight into student learning by observing students' interactions as they tackled both the support tasks and the big task.

> 'It was ... wonderful to sit as part of the group and really see the interactions [between students] and what goes on.' (Teacher 2)

> 'The learning today was in context. Seeing the students go through the activity, observing their actions and interactions allowed me to assess each stage or phase [of their thinking]. Participation allowed me to judge the difficulty of the activity as well.' (Teacher 6)

> 'The types of observations I made were totally different ... the fact that I was able to make observations of children was unique to any in-service.' (Teacher 2)

> 'It was great to be able to interact with the students and see what issues would arise. There are always things that you cannot

Figure 2: Learning by observing students.

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> prepare for, but by doing it in context you are more likely to get a real feel for how things will/should really run.' (Teacher 5)

Teachers' responses also reveal the importance they attach to listening closely to students while working with the group:

> 'If a teacher is not completely immersed in the experience as we were today, they don't pick up the info and pointers that the children are offering in their groups, the frustration in some activities.' (Teacher 1)

> 'Being with the kids today made me realise as I heard them speak we presume a lot as teachers of what they should already know.' (Teacher 10)

> 'What I really like about getting in a small group with them, you're privy to that conversation, which as a teacher at the front you don't usually get.' (Teacher 5)

Teachers' comments also reveal that participating with students in a group as learners was an important part of the PD experience:

> 'You could learn along with the kids through trial and error experiences. You could see and hear their reactions and interactions. You could see things that may need to be changed or adapted because actual students are doing the stuff, not teachers.' (Teacher 4)

> 'I think interacting with students as part of in-service is very beneficial – how else can we understand how this type of teaching will affect them.' (Teacher 2)

> 'It was great to be able to interact with the students and see what issues would arise. There are always things that you cannot prepare for but by doing it in context you are more likely to get a real feel for how things will/should really run.' (Teacher 5)

Figure 3: Learning by participating with students.

> 'Wow! You really have to deal with the model in-context to realise the reality of what happens in science and technology classrooms. By putting myself in the shoes of a student, I realise that we assume too much prior knowledge and sometimes go too fast when we think they should get it. I saw the model really work!' (Teacher 10)

Discussion

The importance of teachers' knowledge of subject matter and pedagogy is well established in the literature (Banks and Barlex, 1999; Rosebery and Puttick, 1998). Yet subject matter knowledge and pedagogy are often fragmented in teacher education and in PD for teachers (Ball, 2000). This study investigated the effectiveness of in-service in context as a way to provide teachers with both subject knowledge and appropriate pedagogy in an integrated way. While the teachers in this study indicated that as a result of the PD they were feeling more empowered to teach science and technology, they also indicated a need for continuous support in the area of improving their subject knowledge and understanding. In the case of technology education, they wanted more practice in tools skills, as well as knowledge of available classroom equipment and materials.

In the early days of the EST project, teachers described how many of their previous PD experiences were too removed from the day-to-day work of their teaching lives to have a meaningful impact. Yet despite a large number of PD days at the faculty, teachers participating in the EST project expressed the need to better understand how students would respond to some of the pedagogical ideas introduced and practised on PD days at the faculty. Teachers' questions inspired the authors to design an alternate context for PD, one that included students. As Putnam and Borko (2000) point out, a focus on the situated nature of cognition suggests the importance of authentic activities in classrooms. Brown et al (1989) defined authentic activities as the 'ordinary practices of a culture' (p. 34) – activities that are similar to what actual practitioners do. The approach adopted in this study was to ground teachers' learning experiences in their own practice by conducting the activity in elementary classrooms. To date, two groups of teachers, one familiar with the EST model and one for whom it was entirely new, have worked and learned alongside students. This provided teachers with the opportunity to observe two instructors team teach a class of children, to see the EST model being taught,

to become an insider in a small group of children, to actively engage in the tasks and to reflect-in-action.

The most appropriate site for PD depends on the specific goals for teacher learning (Putnam and Borko, 2000). Evidence from this study suggests that PD situated in a teacher's classroom may be effective in facilitating teacher understanding of new instructional practices and how to organise a classroom to teach science and technology.

As participating members in a group of Grade 6 students, teachers gained a rare perspective on student learning. No longer were they outsiders briefly observing and attending to several groups in a classroom at the same time. Teachers worked and learned with students as insiders in their groups. They observed first hand how students respond to the support task/big task model, in contrast to usual forms of PD, in which they observe other teachers working. As participants in a group required to complete the same work as students, teachers assumed the role of a learner and to some extent that of a peer.

Being in the group to listen to students' comments and to observe their reactions provided teachers with insights they usually are not able to access. As a teacher overseeing many groups in a classroom, their opportunity to listen to the interactions with each is, of necessity, limited. Further, teachers rarely have an opportunity to watch other teachers teach and to critique how pedagogical practices affect students.

The study has also shown how collaboration between two school boards and a faculty of education can enhance PD opportunities; opportunities for reflection, shared critique, supported change and research. ISIC has manifested an approach to research aimed not only at generating new knowledge and theory but also at addressing the immediate, everyday problems faced by teachers implementing a new curriculum. The ISIC programme of research may be seen as a form of action enquiry, being characterised by four basic elements: collaboration, a focus on practical problems (curriculum implementation), an emphasis on PD and a necessity for time and support of on-going communication (McNiff, 1997). The ISIC research has manifested to a small group of teachers the links between research and classroom practice.

The research has also highlighted the value to both teachers and faculty instructors of ongoing conversations about teaching and learning in EST. ISIC has provided rich opportunities for continuing a conversation about teaching and about learning. These conversations with teachers have prompted the authors, as teacher educators and as PD leaders, to continuously reflect upon our assumptions about PD and to change the ways in which we conceptualise it. We seek to produce new knowledge in conversation with teachers. We seek to challenge teachers to take a stance of critique towards their current teaching practices.

Using a field notes booklet as a data collection tool

While the teachers were completing the support tasks and DMA during Step 1 of ISIC (a technology day), we asked them to concurrently complete a field notes booklet. The booklet contained five sections, each of which contained several questions, as shown below:

- Teaching students to design.
  How successful was the day in helping you acquire strategies for teaching students to design? Please comment on what worked well, what didn't work well and give suggestions for improvements.
- Teaching students to make.
  How successful was the day in helping you acquire strategies for teaching students to make? Please comment on what worked well, what didn't work well and give suggestions for improvements.
- Organising a classroom for designing and making.
  How successful was the day in helping you acquire strategies for organising a classroom for designing and making? Please comment on what worked well, what didn't work well and give suggestions for improvements.
- ISIC as a form of PD.
  How successful was the day as a form of PD? Please comment on what worked well, what didn't work well and give suggestions for improvements.
- Additional comments.
  You are invited to record on this page any additional comments about the experience.

Feedback from teachers during the focus group interview made clear that this was not an effective data collection tool. For example, two teachers told us that it was difficult to respond to questions on designated pages. It was simply too much to do, given that they were already participating in the support tasks and the design and make activity, trying to pay attention to what the students were doing and thinking about the pedagogy in play. Therefore, in Steps 2-4 of the research a much

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simplified field notes booklet was used. The cover page contained the following instruction: ‘Please record your thoughts and questions as they emerge during the day. Use notes, diagrams, mind maps or any other technique that is useful for you.’ 10 blank pages of white paper followed this. Teachers reported this revised version of the field notes booklet as a useful and effective method of recording their thoughts and questions as they emerged throughout the in-service day.

Next steps

The mission statement for the EST project contains two aims:

- to help teachers develop the expertise to answer questions for themselves about teaching elementary science and technology
- to work closely with a small number of teachers who will then share their experience and understanding with others.

The first of these aims has been addressed through the provision of a range of PD experiences at the Faculty of Education and through the ISIC research. The second aim involves devolving the responsibility for PD in EST to the partner boards (i.e. some of the EST partner teachers). Ultimately, the boards’ objective is to provide appropriate PD in science and technology for every elementary teacher.

Achieving this second aim has two parts. First, in Year 3 of the project, four EST teachers led PD days at the Faculty of Education: two teachers led a technology day and two other teachers led a science day. These experiences provided an opportunity for four teacher partners to practise and become accustomed to leading PD in elementary science and elementary technology with colleagues in a ‘safe’ environment.

The second part of devolving responsibility for PD to the school boards is for EST teachers to use the ISIC approach to teach science and technology to non-EST teachers. This represents Steps 5 and 6 in the ISIC programme of research and will provide data as to the efficacy of the model as a tool for the dissemination of good practice to a large audience, i.e. all the elementary teachers in a school board.

Conclusion

The EST project provides multiple contexts for PD, including workshops in technology, science and writing, seminars, individual tutorials and conversations by e-mail and telephone. The ISIC PD model reported in this paper provided teachers with an opportunity to experience a new pedagogic model to support learning in both science and technology education and how this can be enacted in a classroom. This combination of experiences is designed to provide teachers with a deep understanding of teaching and learning in science and technology education. As Lieberman (1995) suggests, the ‘conventional view of PD as a transferable package of knowledge to be distributed to teachers in bite-sized pieces needs radical rethinking’ (p. 591). Evidence from the EST partnership suggests that a combination of approaches situated in a variety of contexts holds the best promise for fostering powerful changes to teachers’ thinking and practices in terms of their pedagogical and subject knowledge.

The authors are encouraged by the results of the research and by the possibilities of ISIC as a form of PD. There appears to be a significant resonance between our findings and the research literature on PD and teacher change, including:

- the potential of partnerships to provide sustained PD opportunities for teachers
- the benefits of creating a professional community of practice
- the necessity to ground teachers’ learning in practice
- the importance of engaging teachers in authentic activities during PD days
- the need to model new instructional practices
- the importance of integrating new subject knowledge and pedagogy.

Still to be fully determined is the role of EST teachers in the provision of PD in science and technology in their school boards and what model of PD is required to disseminate good practice to all teachers in a school board?

Recent reports (National Academy of Education, 1999; National Research Council, 1999) call for more collaborative forms of research where researchers and professional educators work together to improve educational practices. Moreover, reviews of the literature identify a need to examine the nature and scope of school-university collaborations to better understand what

teacher educators and teachers learn and how to sustain these partnerships (Cole and Knowles, 1996). This study supports the view of Lee and Shulha (1999), which encourages educational researchers to consider the various dimensions and possibilities that exist for collaborative work.

Both the EST project and the ISIC research are demonstrating that educational partnerships have the potential to be generative and professionally beneficial for both teacher educators and classroom teachers. Ultimately, teacher candidates and children benefit from school-university partnerships as they seek to improve the quality of teaching and of learning. Participants recognise that the collaboration has facilitated mutual PD in ways that benefit us all. Both EST and ISIC are making clear that PD needs to be regarded as a continuous cycle of learning, practice and reflection with colleagues. Time and guidance are required if PD is to become an ongoing conversation of reflection and change. Changing the nature of PD has the potential to change the profession at its heart. Using teaching and learning experiences in schools to inform programmes in teacher education requires increasing research attention. There is a need to investigate further the nature and scope of university-school collaboration in order to understand what teachers and faculty members learn and how these partnerships may be sustained. The view of the authors is that one area with potential for collaboration is the provision of sustained PD for teachers.

The authors are also excited by the potential for a follow-up study to investigate the relationship between the ISIC model of PD and improvements in student learning. In other words, what is the impact of ISIC on students' learning? Does it make a difference? While high-quality PD is an important and necessary prerequisite to such improvements, the relationship between the two is complex (Guskey, 2000). New research will address questions about the impact of the PD on the performance and achievement of students and their confidence as learners.

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