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Articles appearing in the journal address issues related to mathematical thinking, teaching and learning at all levels. The focus includes specific mathematics content and advances in that area accessible to readers, as well as political, social and cultural issues related to mathematics education. Journal articles cover a wide spectrum of topics such as mathematics content (including advanced mathematics), educational studies related to mathematics, and reports of innovative pedagogical practices with the hope of stimulating dialogue between pre-service and practicing teachers, university educators and mathematicians. The journal is interested in research based articles as well as historical, philosophical, political, cross-cultural and systems perspectives on mathematics content, its teaching and learning. The journal also includes a monograph series on special topics of interest to the community of readers. The journal is accessed from 110+ countries and its readers include students of mathematics, future and practicing teachers, mathematicians, cognitive psychologists, critical theorists, mathematics/science educators, historians and philosophers of mathematics and science as well as those who pursue mathematics recreationally. The editorial board reflects this diversity. The journal exists to create a forum for argumentative and critical positions on mathematics education, and especially welcomes articles which challenge commonly held assumptions about the nature and purpose of mathematics and mathematics education. Reactions or commentaries on previously published articles are welcomed. Manuscripts are to be submitted in electronic format to the editor in APA style. The typical time period from submission to publication is 8-12 months.

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"The butterfly counts not months but moments, and has time enough"
- Tagore (1861-1941)

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The 2010 Banff workshop on Teachers as Stakeholders in Mathematics Education Research

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University of Montana
&
Günter Törner
University of Duisburg-Essen

Abstract: *The Banff International Research Station (BIRS) for mathematical innovation and discovery held a 5-day workshop entitled “Teachers as Stakeholders of Mathematics Education Research” from December 5-10, 2010. This workshop co-organized by Guenter Toerner (University of Duisburg-Essen), Bharath Sriraman (University of Montana), Klaus Hoechsman (Pacific Institute of Mathematical Sciences, UBC-Canada), and Sharon Friesen (University of Calgary), followed up a successful workshop organized in Oberwolfach, Germany in 2007, and brought together 25 participants from all over the world. Participants included key members of the American Mathematical Society, the German Mathematical Society and the Canadian Mathematical Society, in addition to key educational policy makers from Germany, Austria and Australia. One of the goals of the workshop was to unify approaches to mathematics content presented in textbooks aimed at teacher education, in addition to discussing sustainable models of longitudinal professional development that have been successfully implemented in Australia, Europe, Israel and North America. In this special issue of The Mathematics Enthusiast, the myriad approaches to mathematics teacher professional development are presented and discussed.*

Keywords: BIRS; Mathematics teacher professional development; Models of professional development; Mathematics education policy; Mathematics education research (MER); Professional development (PD)

Introduction

Mathematics education has long been concerned with the training of pre-service and in-service teachers. The origins of the field indicate that initially mathematicians like Felix Klein spent a considerable amount of time in producing coherent textbooks for teachers that focussed on the mathematical content (Sriraman & Törner, 2008). In the last three decades teacher training has been the focus of numerous initiatives not limited to the U.S but in different parts of the world. A considerable amount of mathematics education research has reported on start-up projects with teachers, models of professional development, summer workshops, design based approaches to professional development (Lesh & Sriraman, 2010). The discussion at Banff at this workshop centred on whether or not teachers were viewed as stakeholders in the burgeoning body of reported research, and whether or not extant mathematics education research (MER) had any effect on teaching practice when viewed longitudinally. The meta-issue surrounding MER in the discussion among the participants

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was to make the ensuing issues more teacher inclusive than researcher oriented. Not every agenda needed to be perceived as a research agenda! The issues discussed were:

Issue 1: Interest

How deeply do we expect teachers (as stakeholders) to have an interest in the process and the result of a MER project? How can MER help / address the current (de)professionalization?

Issue 2: Distrust - trust

How can we work together to build trust so that our combined work can be more effective and useful for both - researchers and teachers?

Issue 3: (De)Professionalization

Teachers are professionals but not viewed as such. Unlike other fields like medicine, law and others, apprenticeship/internship/mentorship is under-valued.

Issue 4: MER Researchers/Professionals as a Resource

Need to look at teacher's agendas both a priori and emergent if mathematics education researchers want to be accepted within the teacher's milieu.

Issue 5: Terminology

How do we conceive professional growth of teachers ideally?

Issue 6:

How can the relationship (evidence, scalability, sustainability) help enhance MER teachers' learning and transformation of teaching mathematics?

Themes and Issues

Participants were broken up into smaller groups to discuss the six issues listed above. The following themes emerged as a result of the discussion among the participants.

1. Teachers have interest in results that effect teacher's effectiveness.
2. Research results should have an impact on students.
3. Teacher educators have a direct relationship to teachers, but not to their students and teachers tend to just talk about their students' work. This makes communication difficult for the teacher educator.
4. Teachers in Canada are very interested in lesson studies.
5. We need a learning culture for teachers. Thereby most important is "learning in practice from practice".
6. Do we have examples of evidence-based teaching?
7. We do not have professionalism in math teaching when we compare it to other disciplines like medicine.

After lamenting on the current state of secondary math teacher preparation, time was spent discussing issues 3 and 5, namely addressing the current de-professionalization of teachers and models of pre-service education and ongoing professional growth. It was emphasized that mathematics teachers need to consider themselves as professionals with ongoing duties to the subject matter and continually striving for better pedagogical understanding and

reaching for innovation in their teaching strategies, as is supported by current research in mathematics education. They should have the confidence to consider themselves as mathematicians as well as possessing the multiple competencies required to respond to the dynamics in the classroom.

From this arose an ideal vision of the pre-service education of secondary math teachers: mathematics courses that are commonly taken by math majors, including the history of mathematics in concert with specialized math education courses. This will only be possible with the committed involvement of mathematicians in the math education of teachers.

With respect to professional growth, it was strongly felt that research on the current state of teacher knowledge (subject matter and pedagogy) must be undertaken. There were obvious institutional barriers to revealing this deficit and this would require respectful support from within the profession.

The workshop consisted of several teachers from Calgary Girl's School. The model of teacher collaboration at this school was deemed as admirable (e.g., Jarry –Shore & Sandra Mcneil, this issue). In this school, novice teachers were supported and professional development was handled in house and at the instigation of the teachers themselves. Collaboration with mathematics education professionals at the University of Calgary enabled innovation to be fostered at the school. The school was obviously a local centre of excellence but communicating and extending innovations to a larger scale was seen as problematic and would require enormous institutional change.

It was felt that teachers must take the responsibility to be aware of current research in mathematics education and also have input into the nature of math education research projects. Effective communication between mathematics education professionals and teachers is the start.

Discussion

The discussion began with outlining students' misperception of the discipline of mathematics as negative, tedious, and task-oriented (the slippery fish image). Influenced by Roger Howe's presentation on the deficits of mathematics education in the US, comments were made regarding a lack of understanding of symbolism, and incomplete understanding of operations, and no knowledge of the history of mathematics with the foundational deficits occurring at the earliest stage of instruction(primary school). The concern was how to help teachers communicate the beauty of mathematical ideas and their existence within a landscape of reason. We agreed that the subject needed to be humanized by communicating the enormous and often agonizing efforts of mathematicians throughout history.

Teachers needed help in focusing student understanding of key ideas and structures and building a foundation for their students to recognize and enter the 'corona of reasoning' themselves.

Suggestions with respect to professional growth and development were:

- Help primary teachers attain an adult view of elementary mathematics and their historical underpinnings.

- Help secondary teachers attain an epistemological view of mathematics to be more fully aware of the full landscape of the subject.

Mathematicians are ideally the ones to assist this. In addition, all teachers must have the opportunity to play and reflect on mathematics themselves, in the same manner that teachers encourage their students.

Teacher professional growth and development must enable teachers to uncover basic fallacies in their student's understanding and in their own teaching practice and resources must be present to enable them to remediate these. In addition, if teachers are able to critically evaluate curriculum and resources (specifically manipulatives), they will be able instead to refocus their students effectively on the core concepts at each level. The supporting professional development must have the following characteristics:

- long term and ongoing
- trusting open environment
- access to experts
- serious commitment on the part of the teachers expectations of a long front-end preparation before implementing any new innovations in the classroom continuous mentorship within the local instructional setting time in their working lives to collaborate in mentorship

Another major topic of discussion was: How can we (teachers, researchers, facilitators) work together to build trust so that our combined work can be more effective and useful for both/all? The following were suggested by the participants if we want to achieve a win for everybody (teachers, researchers, students).

- Focus on important maths
- Relevant to teachers' goals/concerns – considered worthwhile by teacher and researcher
- Everyone gets something relevant and valuable out of it
 - Certificate
 - Credits toward academic course
 - Research outcome
- Curriculum based
- Potential to enlighten teachers and researchers about practical issues of use to other teachers
- E.g. Co-authoring classroom materials
- Potential for the growth of knowledge e.g., re student learning, teacher learning ...

Necessary conditions for opening practice i.e. having a researcher in classroom:

- Need to know and understand each others' goals, motivations, constraints; match with own goals. Need to plan the relationship in terms of its beginning, middle and end
- Want to know what each will do, get and how it will be used

How do we achieve this kind of relationship?

- Individual conversations about what each wants
- Time for conversations and working together in less confronting ways
- Time for sustained interaction

- Teacher needs to be seen as the expert on teaching in this class
- Pace/staging of innovation mutually negotiated but ultimately controlled by the teachers and consistent with teachers' beliefs
- Compatibility of personality, thinking, beliefs
- Genuine partnership – shared development of the direction of the project

Barriers:

- Sharing experiences (e.g., publishing practices) can be 'embarrassing' threatening for teachers (and researchers); not part of culture of teaching profession; very exposing
- There is an asymmetry in terms of the risk to teacher and researcher when a researcher enters a teacher's classroom; researchers must be sensitive to this
- Researchers' being critical; fear of being judged
- Opening oneself up to one's peers can be more threatening than to someone perceived to be more skilled
- Comfort level depends on confidence with the particular topic or lesson
- Unrealistic expectation of an 'ideal' lesson
- Unreasonable expectations – e.g., conforming to someone else's model of teaching; trying something that is quite different from usual and unfamiliar and perhaps inconsistent with the teachers' beliefs or teaching styles
- Concern that project might interfere with achieving goals for which teacher is accountable e.g., scores on mandated tests

Teacher Issues

- The need to design their own programs
- Realize the potential to create change
- Mentorship
- Teachers mentoring teachers and provision of work time for teachers to collaborate on professional interests.
- No on the job time
- Restructuring time
- Teachers naturally reach to the curriculum or manipulatives as a crutch or a response to external pressures of PD

Concluding Points

At the end of the workshop, agreements were reached on the following aspects of mathematics teacher professional development.

- Substantial mathematical nucleus is needed
- Be more forward in admitting our own weaknesses
- Validity of the medical model
- Longer term PD versus one day things
- Follow up on long term projects
- Collaborating with a teacher in the same school
- Money thrown by policy makers is not aimed at the teachers that want the PD.
- Dichotomy between wanting and needing PD
- Teachers that want to be learners in the long term

The papers in this special issue focus on the themes outlined in this article and explore various aspects in the concluding points.

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**If you *really* want to get ahead, get a bunch of theories . . .
and data to test them.^{1,2}**

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Abstract: *This paper addresses questions of mathematics teachers' professional development. My goal is not to provide "answers," although I have worked for some years to enhance teachers' capacity to create rich learning environments for their students. Rather, my goal is to problematize the issue, to ask: How do we frame questions of professional development in ways that are theoretically grounded? What theories do you need to know, in order do a good job of professional development? In the light of this kind of theoretical framing, I will discuss two related attempts at supporting teachers in their work.*

Keywords: Mathematics teacher professional development; Theories of teaching; Teaching-in-context

Introduction

To motivate the kind of approach I take in this paper, I begin with a metaphor. Suppose we consider the "problem" of air travel. The analogous question one might ask is: What theories do you need to know, in order do a good job of operating an air travel system?

One might start with grand theories. What does it take to get a plane off the ground? Newton's laws aren't bad for a start. If you're building airplanes, it helps to understand

¹ As readers will recognize, my title is a shameless rip-off of Annette Karmiloff-Smith & Barbel Inhelder's (1975) "If you want to get ahead, get a theory." That's fine for simple problems – but as we'll see, complex problems require more than one theory, even if it's a grand theory.

² This paper is based on two presentations. The first, "Creating Support Structures to Help Teachers Engage in Formative Assessments," was given at the conference "Teachers as Stakeholders in Mathematics Education Research," Banff, Canada, December 5 - 10, 2010. The second, which evolved from the first, was entitled "If you *really* want to get ahead, get a bunch of theories . . . and data to test them," and was an invited presentation at the annual meeting of the American Educational Research Association, New Orleans, April 8 - 12, 2011.

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about gravity. But that's just a start. What about air lift? There are issues of wing configuration, for example; Bernoulli's laws apply there. Note that Bernoulli's laws, which are more "local," are at a different level of grain size than Newton's. Both the grand theory and the second, more local theory are essential. Moreover, to manufacture various parts of the plane you need theories of: metal expansion and contraction; jet propulsion (if you're manufacturing a jet), and relevant theoretical frames regarding the construction of every system (e.g., braking, oxygen, radar, etc.) that the plane will use. In addition, and absolutely essential: All of the theoretical ideas **MUST** be backed by rigorous empirical work, preferably in dialectic with the theoretical. Component systems are refined and tested rigorously before they are used for commercial flights.

All that, of course, is just for the airplane. But what about the human and material contexts within which air travel takes place? Having put together the most advanced and capacious airplane won't do any good if the local airport has a dirt runway and no radar; the technology has to fit the context. Beyond that, there is the question of how one builds a robust infrastructure for dealing with normal and not-so-normal travel-related issues. Recent news photographs of people stranded for days and weeks at airports because of volcanic eruptions or unexpectedly heavy snow make the point that a broad range of systems shape "local" day-to-day operations.

In sum, to make progress on complex, multifaceted issues (and supporting teachers' professional growth is certainly a complex and multifaceted issue!),

We need lots of theories, at different levels of grain size;

The theories should be refined and tested empirically;

The systems and practices one builds must be context sensitive and adaptable.

This last point implies that there is no "one size fits all" solution to issues such as professional development.

Now, let us turn our attention to the issue of teachers' growth and development. I will argue that to address this issue in a reasonable way, one should be informed by (and contribute to the development of) theory related to:

- The dimensions of competency one would like to see develop;
- *How* things develop;
- A theory of change, and a plan embodying the theory;

All of which must be context- and material resource-sensitive, which means that it is also necessary to have

- A theory of individual learning and growth, and
- A theory of how ideas can be spread or squashed in a social (i.e., district, state) context.

In what follows, I will lay out some of our theoretical ideas about (mathematics) teachers' proficiency and its development, describe some current efforts to promote teachers' professional growth and say why I am worried about them, and frame the enterprise in terms of a larger, (prospective) data gathering effort. My hope is that the kind of effort one can envision based on the consideration of such ideas would be an appropriate way to approach teacher preparation and other heretofore intractable problems.

Theoretical backdrop

Theory, Part 1. Dimensions of teaching proficiency.

If one is engaged in supporting teachers' professional growth, it helps to have a theory of the dimensions in which one hopes teachers will grow. To sum up a chapter in a table, Schoenfeld and Kilpatrick (2008) offer a provisional framework for looking at the dimensions of teacher proficiency.⁴ See Table 1.

⁴ Schoenfeld and Kilpatrick's chapter is specifically about dimensions of mathematics teachers' proficiency. However, I believe that the framework is general, in that one could replace "mathematics" with any other content domain, and it would remain valid.

Knowing school (mathematics) in depth and breadth
Knowing students as thinkers
Knowing students as learners
Crafting and managing learning environments
Developing classroom norms and supporting classroom discourse as part of “teaching for understanding”
Building relationships that support learning
Reflecting on one's practice

Table 1. A Provisional Framework for Proficiency in Teaching Mathematics

To presage what lies ahead, I shall not try to address all seven of these dimensions in this paper. What I will argue is that many of the proficiencies characterized in Table 1 are embodied by teachers who attend to student thinking in formative ways – teachers who building on student understandings and find productive ways to address student misunderstandings. Thus, I will argue, a productive focus for professional development is to help teachers engage in formative or diagnostic teaching (grounded in rich content-based understandings, of course).

Theory, Part 2. A theory of teachers' in-the-moment decision making.

At a more fine-grained level, the consequential question in the classroom is, what “moves” is the teacher going to make, and why? Here I shall do my best to condense a book into a page or so. The key assertion in Schoenfeld (2010a), which builds on Schoenfeld (1998; 2000; 2008), is that *teachers' in-the-moment decision-making is a function of their knowledge/resources, goals, and beliefs/orientations*. The major theoretical-empirical claim in that body of work is that if one knows “enough” about a teacher’s resources, goals, and orientations, one can model his/her actions and explain

them on a line-by-line basis. Here I will just suggest these three categories are “make or break” elements of effective teaching.

Little needs to be said about knowledge or resources: the importance of subject matter knowledge, general pedagogical knowledge, and pedagogical content knowledge is well understood. And, it goes without saying that material and social resources are highly consequential (cf. Kozol, 1992).

Thompson’s (e.g., 1992) pioneering work on teacher beliefs established their importance; here I just describe one story to indicate the way they play out. Some years ago I sat in on a year-long geometry course in which the teacher took a very procedural approach to the mathematics: “First do this, then do that,” etc. One day I asked him if he had ever thought of just giving the students a problem and seeing what they might do with it. “Not these kids,” he said; “it would just confuse them. I might do that with my honors students” (and he did). To sum up in brief: he had the knowledge and skills to teach this group of students very differently. But, his beliefs about what the students were capable of doing and what was thus an appropriate pedagogy for them resulted in his choosing an approach that actually deprived them mathematically! (One can see analogies in reading groups, where high-flying readers get to discuss important ideas about the text, while other students are focused by the teacher on decoding.)

Finally, anyone who has seen the distortion of classroom practice because the teacher devoted days if not weeks to drilling students in preparation on low-level but high-stakes multiple choice standardized tests knows how the choice of goals for students can make a *big* difference.

In sum, any serious look at professional development should be concerned with the growth and change of teachers’ knowledge/resources, goals, and beliefs/orientations.

Theory, Part 3. A Hypothesized Development Space: Dimensions of Teacher Growth⁵

In different countries, different styles of teaching (for example, depending on well constructed lectures as the primary form of instruction, or depending on having students interact with each other) tend to be valued differently (see, e.g., Stigler and Hiebert, 1999). Thus, the ideals to which teachers aspire will vary; and the trajectories toward those ideals will vary. In this section I am not suggesting a universal trajectory, but, rather, one that is consistent with my values as a researcher and professional developer, and that is consistent with developmental trajectories in the United States and some other nations (see, e.g., Fuller, 1969; Hord, Rutherford, Huling-Austin, & Hall, 1987; Lesh & Sriraman, 2010; Ryan, 1986; Smith, 2000).

From my perspective, a particular form of teaching expertise that is highly valuable and worth aspiring to is the ability to conduct “diagnostic teaching.” This kind of teaching, in which teachers make significant use of formative assessment to see what their students understand, and shape their lessons according to what they discover about their students, exemplifies the productive use of pedagogical content knowledge as first described by Shulman (1986, 1987), and is consistent with the kind of teaching described in the U.S. National Council of Teachers of Mathematics’ (1991) *Professional Standards for Teaching Mathematics*. In diagnostic teaching (or, teaching with a heavy emphasis on using formative assessments), the teacher has specific mathematical goals. In addition, the teacher recognizes that students have varied understandings of the mathematics under discussion. He or she probes for what the students know and then responds in ways that address errors and misconceptions, and that build on student understanding, to move the students toward the instructional goals.

Diagnostic teaching is a form of instruction to which some teachers in the U.S. aspire. This form of teaching is not well supported by typical teacher preparation programs, or what are called “in-service” or ongoing professional development programs for teachers. In the U.S., one sees typical development toward diagnostic teaching as represented in Figures 1, 2, and 3. Each figure includes three planes of teacher activities: “managing”

⁵ This section is modified from Schoenfeld (in press).

the classroom, having students engage in mathematically productive and (one hopes) engaging activities, and engaging in diagnostic teaching. Typically, beginning teachers in the U.S. are still learning to manage classroom activities, and a large amount of their time and attention is devoted to this: see Figure 1.

Figure 1. Levels of proficiency and time allocations of a typical beginning teacher. (The degree of shading in the planes represents the level of proficiency, and the arrows point to the percentage of time devoted to each plane of activity.) Reprinted with permission from Schoenfeld, 2010a.

As teachers become more proficient they spend less time on classroom management, both because they are better at it and because students who are actively engaged in doing mathematics do not need to be “managed” as much as those who are not productively engaged. Figure 2 provides the typical profile of an “accomplished” or “proficient” teacher.

Figure 2. Levels of proficiency and time allocations of a typical accomplished teacher. Reprinted with permission from Schoenfeld, 2010a.

Many teachers – perhaps the majority of experienced teachers in the U.S. – have profiles as represented in Figure 2. A much smaller percentage of teachers engage, to any significant degree, in diagnostic teaching. When it is well done, diagnostic teaching is very responsive to student understandings, and it is likely to be engaging; as a result, classroom management does not require much time and attention, and the students are involved in productive mathematical activities a large percentage of class time. This kind of teaching, when well done, results in a profile such as the one given in Figure 3.

Figure 3. Levels of proficiency and time allocations of a highly accomplished teacher. Reprinted with permission from Schoenfeld, 2010a.

From my perspective a major challenge for professional development is to help teachers develop the resources, goals, and orientations that enable them to function in the ways represented in Figure 3. As indicated above, this is of necessity a slow process: even if a teacher has aspirations to teach in a particular manner, it takes some time to develop the resources (e.g., pedagogical content knowledge) that support teaching in that way. Some beginning attempts to provide teachers with that kind of support are described below in the next section.

The categories identified immediately above are not independent; they are deeply intertwined. For example, beliefs and goals “recruit” resources, in that the knowledge that becomes salient to a teacher is that which is relevant to current beliefs and goals; but resources constrain progress toward goals, in that (for example) a teacher who adopts a new set of goals may not have the resources with which to achieve them. (Cf. Cohen, 1990; Toerner, Roesken, Rolka & Sriraman, 2010). Moreover, the main point of *How we*

Think (Schoenfeld, 2010a) is that knowledge and resources, goals, and beliefs and orientations are all deeply intertwined. One has, thus, the following Serious Theoretical Corollary: *The evolution of professional competency is, of necessity, slow.* (Of course, this comes as no surprise: across the boards, the literature says that the development of expertise in any field takes 5,000-10,000 hours of focused, reflective action.)

In sum (a fact known to everybody in the business): there can be no “magic bullets” in professional development.

Theory, Part 4. Individual growth and change.

There is an obvious but often overlooked fact, which was specifically noted in the expanded edition of *How People Learn*: the conditions that are appropriate for children as learners are also appropriate for adult learners! Thus,

Learning environments for adults (e.g. professional development programs) must be

- Learner Centered
- Knowledge Centered
- Assessment Centered
- Community Centered (NRC, 2003, pp. 36-7)

Theory, Part 5. Institutional Surround and the need for coherence.

Systemic incoherence is the death knell of professional development. Specifically, there is evidence that there can be significant progress within a school district when:

- There is a set of high standards
- Curriculum is aligned with those standards
- Assessment is aligned with those standards
- Professional development is aligned with those standards
- There is enough stability for growth and change to take place.

If any of these are lacking, the chances for progress are significantly diminished. (See, e.g., Schoenfeld, 2006; 2009.)

I note that these comments, which focus largely on the conditions for classroom coherence, are consistent with a broader institutional perspective on the conditions needed for progress in urban school districts. For example, Bryk et al. (2010) identify the following “essential supports” at the systemic level: leadership as the driver for change; parent-community school ties; professional capacity; instructional guidance; and a student-centered learning climate.

Two practical attempts to make a difference.

To put things simply (and putting it this way to remind myself that all of what we do is a matter of values): The central issue of professional development is how to help teachers, over time, develop some of the skills and understandings we value.

As noted above, my focus in this paper, and in my work with teachers, is on formative assessment or “diagnostic teaching.” I begin, here with a few words about formative assessment, to distinguish it clearly from summative assessment.

Summative assessments show what students “know and can do” *after* instruction. That’s important, but it’s too late to help the students learn. In contrast, formative assessments reveal students’ current understandings so you can help them improve. There are some important issues to understand about formative assessments:

1. Formative assessment is not summative assessment given frequently! Pacing guides with monthly or biweekly scored exams may keep teachers and students in line, and let both know how well they are doing (in terms of scores at least), but they are not the same as formative assessment – especially because of the next point.
2. Scoring formative assessments rather than, *or in addition to*, giving feedback destroys their utility. Unscored comments help students learn; when papers are also scored, students don’t read the comments. (Black & Wiliam, 1998).

3. Learning to attend to student thinking, and build on it, is difficult for teachers to do (at least in mathematics, but I suspect more generally. It's clearly the case in the sciences, given the misconceptions literature).
4. Thus, it is useful to provide teachers with tools to help them make effective use of the information that formative assessments provide.

In consequence, the central question I address in my professional development work is:

How can one support teachers in doing formative assessments, as a mechanism for the teachers' professional growth and to the benefit of their students? In what follows I will describe two synergistic but different attempts to do so:

- I. The National Research Council's SERP (Strategic Educational Research Partnership) collaboration with San Francisco, and
- II. The "Mathematics Assessment Project," or MAP, funded by the Bill and Melinda Gates Foundation.

In the San Francisco SERP partnership, we have collaborated with teachers from San Francisco Unified School district to create instructional support materials ("formative assessment lessons"; see below for a description) for grades 6, 7, and 8. For a description of SERP, see Donovan & Pellegrino, 2003, or the link at <http://www.serp-institute.org/content/index.php>. MAP is a joint project between U.C. Berkeley and the University of Nottingham, in collaboration with the Silicon Valley Mathematics Initiative and Inverness Research Associates. The goal of the MAP project is to create and distribute, free for non-commercial use, a spectrum of summative assessments and formative assessment lessons. Some summative assessments and many of our formative assessment lessons (including the full formative assessment lesson that addresses instructional challenge 2, described below) can be found on the project web site, <http://map.mathshell.org/materials/>. For a discussion of the process of designing such lessons, see Swan (2008). For a comprehensive treatment of related design issues, see Swan (2005).

A major goal of both projects is to help teachers develop the kinds of skills, understandings, habits of mind, supportive beliefs, etc., that will enable them to engage in formative or diagnostic teaching. As suggested by my air travel metaphor, what one needs at minimum in order to address large-scale, socially embedded issues such as professional development is:

- A focal mechanism for helping teachers teach in formative ways, and
- A cultural surround that supports the “take-up” of the focal mechanism.

I address both in turn.

The focal mechanism

A major part of the mechanism at the heart of our professional development work in both projects is what we call the *formative assessment lesson*.

In simplest terms, a formative assessment lesson includes a rich “diagnostic” problem, and things to do when one sees the results of the diagnosis.

What follows are two examples of instructional challenges around which we have built formative assessment lessons and brief descriptions of attributes of the packages themselves. The idea, in brief, is that a formative assessment lesson is designed to provide enough lesson scaffolding to enable teachers who use the materials we design to teach, with moderate success, a formative or “diagnostic” lesson.

Instructional Challenge 1: In their algebra or pre-algebra classes students learn the point-slope formula for a line, and sometimes other formulas such as the two-point formula. However, they often have trouble crafting graphs if the information they are given is not in “standard form.” More generally, although students may know that there are various formulas for the equation of a line (the point-slope formula, the two-intercept formula, etc.) they rarely understand that the formulas are specific instantiations of the following general fact: knowing any two pieces of information about a line (e.g., two points on it, a point and the slope of the line, the two intercepts, a point and a rate of change, . . .) will enable you to determine the graph and equation of the line.

The way we approach this challenge is to first give students a “mystery” - a story about a stolen pie⁶. Students are told that passengers on a bus saw the pie on a ledge when they were riding northward, but that the pie was gone when the bus made its return trip. They are given the information about the whereabouts of a number of suspects, for example, where Tom lives, and the fact the Tom left his house for a walk at 4 PM, walking 9 miles north to arrive for dinner at 6:15 PM. See Figure 4.

⁶ The inspiration for this task was an enrichment activity in a Prentice-Hall algebra text book (Smith, 2001).

WHO STOLE THE APPLE PIE?

The Mystery...

Ms. Lee lives 24 miles north of Oakville on the way to Albany. She baked an apple pie and set it out on her windowsill at 3:00 pm to cool. She went to get it at 6:30 pm and found it had been **STOLEN!**

Tom, Dora, Harry, and Joan, who all live on the road between Oakville and Albany, are the main suspects. Ms. Lee needs you to use the following information to solve the mystery of who stole the pie, and find the thief.

THE BUS DRIVER: A **bus** left Oakville at 4:00 p.m. going nonstop to Albany, 30 miles north. The bus arrived in Albany at 4:45 p.m., waited 15 minutes, and then returned to Oakville at the same rate. The driver saw the apple pie on Ms. Lee's windowsill as she drove north, but it was gone when she passed by on the way south back to Oakville.

<p>TOM</p> <p>Tom lives 17 miles north of Oakville. He left home at 4:00 p.m. and walked 9 miles north to arrive at Curley's Burger Stand for dinner at 6:15 p.m.</p>	<p>DORA</p> <p>Dora lives 12 miles north of Oakville. At 3:00 p.m., she left home and rode her bicycle north at 9 miles per hour to the bus stop in Albany.</p>
<p>HARRY</p> <p>Harry left his house, 2 miles north of Oakville, at 3:30 p.m. He drove north for a half an hour at 36 miles per hour.</p> <p>He stopped at the Science Museum for 45 minutes. He then drove to Curley's Burger Stand, 26 miles from Oakville, arriving there at 5:00.</p>	<p>JOAN</p> <p>Joan was at her house, across the street from the Science Museum, 20 miles north of Oakville, until 5:00 p.m. She then jogged north for one hour at 6 miles per hour.</p> <p>She stopped at Curley's Burger Stand for a soda and met a friend.</p>

Figure 4. The Apple Pie Problem.

The given information allows one to rule out all but one suspect – but, if one tries to reason one's way through the problem directly, it is very hard to keep track of all of the relevant information. Thus, the first meta-lesson for the students (who are given the mystery the day before the lesson) is that graphing can be useful!

The lesson packet for the teacher includes a complete set of instructional materials (summarized below) and a lesson plan. There are also sections designed to help the teacher make effective use of the materials. There are teacher-to-teacher notes, intended to explain our approach. The notes for this lesson include the following:

- Without the use of graphing, this problem is VERY hard to solve! That's why we give it as a "teaser" the day before. If the students see how hard it is to solve without the graphs, they'll appreciate the use of the graphs when they work through the problem.
- There are a lot of words in this problem. That's deliberate. Our goal is to help students with second language or other linguistic challenges to make sense of the problem situations, rather than simplifying the language into "bite-size" pieces that no longer represent typical spoken or written English.
- The question sets are written so that they will reveal student misunderstandings. Extra questions below are intended to do the same. A series of pointed questions will often get students to see the correct mathematics; or when they explain what they have done correctly, it will be reinforced. Then they will remember it better.

There are notes on expected student difficulties, for example,

- Students are likely to have difficulty seeing that a fixed object, such the pie on Ms. Lee's windowsill or the bus station in Albany, is represented as a horizontal line segment on a distance-versus-time graph.
- The x-axis represents time. Some students may not be able to locate "fractional times" (e.g., 3:30) as points on the axis, and some may be confused because the x-values do not start at 0. Similarly, that some people's trajectories start in the "middle" of the graph may be confusing.
- Understanding that the coordinate pair (time, location) corresponds to a where an object is at some point in time – e.g., answering the question "Where is everyone at 4:15 PM?"

- Interpreting rates such as 18 mph, especially when a person is traveling for less than 1 hour.
- Understanding simultaneity – that when two graphs cross, the two things represented are at the same place, at the same time.
- Seeing that steeper lines mean greater speed.

For each of the expected difficulties there are some suggestions regarding questions the teacher might ask the students, in order to help them address those difficulties. In addition, there are samples of student work, which allow the teacher to see what his or her students are likely to produce, and a discussion of how the issues the student work raises might be addressed.

There is, of course, a lesson plan, and a full set of lesson materials. These materials include a “starter” graph (Figure 5), which the teacher uses to get the students going on the task:

Who Stole the Pie? Graph
On the graph, plot the travels of the bus, Tom, Dora, Harry, and Joan. Assume everyone traveled constant rates.

Figure 5: The starter graph.

The students are also given a set of “Getting Started” questions to address:

- Where are Oakville and Albany on the graph?
- What is the meaning of the horizontal line at the point 24 miles north?
- How is the x-axis different from other x-axes you’ve worked with?
- Where would you find 4:30 on the x-axis?
- Why does the line for the bus have a horizontal section?
- How would you graph the bus’s return trip?

Figure 6. Getting started” questions”

These are followed by a series of question sets that the students work over the course of the lesson (which may take two to three days):

Question Set I

Use your graph to answer these questions and solve the mystery. Use extra paper if needed to give complete answers to each of the questions.

- Which of the suspect’s graphs did you find easiest to graph? Explain why.
- Which of the suspect’s graphs did you find most challenging to graph? Explain why.
- Who stole the apple pie? Write a convincing explanation about how you know who is guilty and who is innocent.

Question Set II

Use your graph from Who Stole the Apple Pie to answer these questions. You need to be able to explain your answers.

- Where are each of the characters in this problem (Tom, Dora, Harry, Joan, the bus, and the apple pie) at 4:15? Explain how you know this.
- Who stops at Curley's Burger Stand? How does the graph help you see when each person arrived at Curley's Burger Stand?
- When did Dora bike past Curley's burger stand? How can you figure this out from the graph?
- Does Harry drive at the same speed from his house to the museum as he drives from the museum to Curley's? Explain how you figured this out.
- Who does Tom see on his walk? When does Tom see the bus pass him?

Question Set III

- Write two questions (similar to those in Question Set II) that can be answered using this graph. Include the answers after your questions.
- You find out that Edward is also a suspect. Here is his "graph" (not shown). Write a story to fit his graph and decide if he could have been the thief.

These questions provide students with an opportunity to grapple with the relevant mathematics and to reflect on their thinking and learning. The questions are discussed in small groups as the class works on them, and then in whole class discussions.

In sum, this lesson tries to support student learning through question-asking, and tries to support the teacher by highlighting issues that are likely to arise and discussing things the teacher can do about them. (The teacher who co-designed this lesson, Shauna Poong, likes to have the questions in written form for her students. This way they all get to address all the questions when they (or their group) is ready, and she can circulate through the classroom working with small groups or individual students.)

The cultural surround for this lesson is discussed following the presentation of the second instructional challenge.

Instructional Challenge 2: We know that students have many graphing misconceptions, e.g., confusing a picture of a story with a graph of the story in a distance-time graph. The following lesson, designed by Malcolm Swan, addresses that issue directly⁷.

The lesson sequence begins with a pre-assessment, a task that serves to reveal what the students understand about distance-time graphs and what might be problematic for them. The students work the pre-assessment the day before the full lesson, providing the teacher the opportunity to analyze student responses, observing student strengths and seeing what is problematic. In preparation for the full lesson, the lesson packet provides the teacher with a set of common student issues. One such example is:

Student interprets the graph as a picture

For example: The student assumes that as the graph in “Matching a graph to a story” (Figure 6) goes up and down, Tom's path is going up and down.

Or: The student assumes that a straight line on a graph means that the motion is along a straight path.

Or: The student thinks the negative slope means Tom has taken a detour.

To address such issues, the lesson packet offers a corresponding set of suggested questions and prompts. For the issue above, for example, the packet offers the following:

Suggested questions and prompts.

- If a person walked in a circle around their home, what would the graph look like?
- If a person walked at a steady speed up and down a hill, directly away from home, what would the graph look like?
- In each section of his journey, is Tom's speed steady or is it changing? How do you know?

⁷ As noted above, the full lesson can be downloaded from the MAP web site, <<http://map.mathshell.org/materials/>>. Thus this discussion is more telegraphic than the discussion of challenge 1.

- How can you figure out Tom's speed in each section of the journey?)

The lesson itself begins with a task for individual work and then group discussion. The task, “Matching a graph to a story,” is designed to elicit typical misconceptions, so they are “aired” in classroom discussion. See Figure 6.

Figure 6.

After the class has discussed this task – but not resolved it – the students are given a first card sorting activity, in which they are asked to match a series of distance-time graphs with a collection of stories – see Figure 7 for some of the graphs, and figure 8 for some of the stories.

Figure 7. The first six graphs for the card sort (there are 10)

1 Tom ran from his home to the bus stop and waited. He realized that he had missed the bus so he walked home.	2 Opposite Tom's home is a hill. Tom climbed slowly up the hill, walked across the top, and then ran quickly down the other side.
3 Tom skateboarded from his house, gradually building up speed. He slowed down to avoid some rough ground, but then speeded up again.	4 Tom walked slowly along the road, stopped to look at his watch, realized he was late, and then started running.
5 Tom left his home for a run, but he was unfit and gradually came to a stop!	6 Tom walked to the store at the end of his street, bought a newspaper, and then ran all the way back.
7 Tom went out for a walk with some friends. He suddenly realized he had left his wallet behind. He ran home to get it and then had to run to catch up with the others.	8 This graph is just plain wrong. How can Tom be in two places at once?
9 After the party, Tom walked slowly all the way home.	10 Make up your own story!

Figure 8. Stories to be matched to the graphs in Figure 7.

The matching activity gives rise to lively debates, as the students realize that two incompatible stories have been matched to the same graph, or that they want to attach the same story to two different graphs. After the students have discussed these issues for a while, the class is given the “mediating” tables of values in Figure 9. By considering how

a story would generate a distance-versus-time table, and then graphing their table, the students can iron out many of their difficulties.

P	Time	Distance
	0	0
	1	40
	2	40
	3	40
	4	20
	5	0

Q	Time	Distance
	0	0
	1	10
	2	20
	3	40
	4	60
	5	120

R	Time	Distance
	0	0
	1	18
	2	36
	3	54
	3	84
	5	120

S	Time	Distance
0	0	
1	40	
2	80	
3	60	
4	40	
5	80	

T	Time	Distance
	0	0
	1	20
	2	40
	3	40
	4	40
	5	0

U	Time	Distance
	0	0
	1	30
	2	60
	3	0
	4	60
	5	120

V	Time	Distance
0	0	
1	20	
2	40	
3	40	
4	80	
5	120	

W	Time	Distance
	0	0
	1	45
	2	80
	3	105
	4	120
	5	125

X	Time	Distance
	0	120
	1	96
	2	72
	3	48
	4	24
	5	0

Y	Make this one up!	
Time	Distance	
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Z	Make this one up!	
Time	Distance	
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Figure 9. Data tables for the distance-time card sort.

The full lesson package provides a lesson plan and various other supports for the teacher.

The cultural surround.

The previous section describes the formative assessment lessons we have been producing. The question, then, is: How do they fit into a coherent program of professional development? This is where context and a host of social issues arise.

Among the issues one needs to confront in providing a productive professional development context for the use of these lessons are the following:

- How might one make these ideas accessible to individual teachers;
- How one might foster the individual changes in knowledge, habits of mind, beliefs consistent with this approach; and
- How to consider larger social & professional context things that shape perceived opportunities (or lack thereof).

Here, first, is the story with regard to SERP.

We (my students and I, some San Francisco Unified School District personnel, and some others) have worked with 6 teacher “co-developers” over a period of years. We started by focusing on attunement to student thinking, and moved on to develop and teach lessons of the type in the appendices. (“Who Stole the Apple Pie?” is one of our 8th grade lessons.)

Our first attunement technique, aimed at attending to student thinking, was to ask our partner teachers to interview some of their students⁸. We gave them tape recorders and asked them to pick students in whom they were interested, and then interview the student as he or she worked a typical problem from the curriculum.

A seventh grade teacher interviewed a particular student because she felt that the student did not belong in her class. This student’s homework had never revealed more than “chicken scratches on the page,” providing no evidence that she was following the material. The teacher chose to interview the student in order to get a better sense of what

⁸ This discussion is radically condensed from Schoenfeld (2010b).

she knew and did not know. For the interview she chose a problem straight from the curriculum:

A five-pound box of sugar costs \$1.80 and contains 12 cups of sugar. Marella and Mark are making a batch of cookies. The recipe calls for 2 cups of sugar. Determine how much the sugar for the cookies costs.

This task is linguistically complex, especially for second language students. Many students had had difficulty with this problem, and the teacher expected this particular student to struggle. She asked the student to read through the problem and then to think out loud as she worked on its solution.

In the interview the student did some very sensible things – and then produced some incomprehensible chicken scratches on the page. (The result of her dividing 1.80 by 12 was “.13.3 cents.”) When the teacher asked the student for an explanation, the student made it clear that to get the cost of one cup of sugar she had to divide \$1.80 by 12; then she had to double that number to get the cost of the sugar needed for the recipe. Moreover and unlike many students, she checked the reasonableness of her answer. She knew she had done something wrong because the numerical value she had obtained did not fit the conditions of the problem.

When the teacher brought this tape to the SERP meeting, she was radiant. “I thought the student didn’t belong in the class,” she said. “All I’d seen were chicken scratches on the page. But now I see she totally gets it conceptually; she just has problems with the algorithms. She definitely belongs in the class, I can do remediation on the algorithms.”

The teacher paused, shook her head, and then said, “I had a completely wrong impression of her . . . Oh my god, I’m going to have to interview all my students!”

In short, our discussions focused on student thinking. This focus made a difference, and resulted in our basing some instructional techniques on what we observed in typical student behavior. (For example, students tend to do what one teacher called “number mashing,” combining the numbers in a problem statement before they understand the conditions of the problem. We developed classroom techniques to forestall this.)

Now, what I have just described . . . is what I truly believe is a wonderful teacher-researcher community that has stimulated real professional growth for all concerned. However, it may be the world's most expensive per capita professional development program for 6 teachers.

The real question is, How do we get these ideas out to the larger San Francisco teaching community? As indicated, we build formative assessment lessons, which contain a fair amount of support structure.

But that isn't enough, for a number of reasons – the first of which is that what we're trying to do is embody a particular approach to teaching, and we have seen that teachers can take the lesson packages as *scripts*, following the letter of the lesson rather than its spirit. This is not what we intend. We want teachers to be able to work in the spirit of the lessons.

We do have a mechanism to address this issue. The idea is to provide a “surround” for the lessons, which will (if all goes according to plan) be available on the web for all of the district's teachers. Here is a (somewhat idealized) version of how that process works.

First, teacher-researcher dyads (called co-developers) develop the lessons.

Second, a teacher co-developer teaches the lesson in collaboration with the researcher co-developer. We videotape:

- a pre-lesson interview, in which the focus is on what the teacher is trying to learn about the students and what the lesson is supposed to reveal;
- the lesson itself, focusing largely on student work;
- a post-lesson interview, in which the focus is on what the lesson revealed about student thinking and how it might be modified to be more effective.

Third, we create a package of materials that contains the lesson, annotated student work, and teacher comments. This package includes video records (from the taped lessons) that serve as opportunities for focusing on student thinking and how to build on it.

Fourth, the other teacher co-developer at the same grade level goes through the same process with the lesson package. He or she teaches the same lesson and annotates the resources with his/her own comments.

This should, we hope, produce shareable resources grounded in instruction. We have a lovely development plan, tying our packages to the district's curriculum and assessment schedule. If all goes well, by the end of next academic year all of this will be available through the web to all of San Francisco's middle school teachers.

Let us, for the moment, view all this through rose-colored lenses. These are just materials. There are still issues of how you really get things out to a district, in ways that make a difference.

It's time for a brief theoretical interlude:

Theory, Part 6: "Spread"

On the one hand, we know that top-down mandates from a district tend to die rapidly. Teachers who are not enthusiastic about the latest, greatest top-down ideas know how to "duck and cover."

On the other hand, we know that bottom-up activities are hard to maintain, and lose momentum. Innovators tend to burn out. (McLaughlin & Talbert, 2001).

How might one cope with this? Imagine a hybrid, justified in part by social network theory? (see, e.g., Coburn & Russell, 2008). One can envision a scheme where the district introduces the idea of SERP lessons, but the SERP teachers are the experts who provide much of the district-wide live professional development. (Recall, there should be an extensive web support network as well.) In this way, the SERP teachers are given credibility as lesson developers by the district, and the teachers see themselves as being helped by their colleagues rather than as the simple victims of a top-down mandate.

This, as noted above, is the rose-colored version. I'll get to the need for data in a moment.

Now, let's return to the issue of the cultural surround.

What about districts where we don't have such access or resources? How does one provide a cultural surround, and the grounds for the development of the appropriate pedagogical practices and habits of mind, absent the kinds of support potentially available in the San Francisco Unified School district?

That's the Mathematics Assessment Project. MAP is producing 20 formative assessment lessons per grade, targeted to central concepts in the Common Core State Standards. The Gates foundation will make these lessons available to all, on the web, at no cost! Thus, any school district can have access to these materials. In addition to the 20 lessons at each grade addressing core content via formative assessment, there will be some videotapes for each grade showing teachers how they might work with other teachers at their school to build a teaching community that supports the productive use of such formative materials.

Twenty lessons of one-to-two-day length amount to a substantial part of the curriculum. Our hope is that, having taught 20 formative lessons, even if by partly following a script, teachers will see the value of such an approach and perhaps even begin to develop habits of mind consistent with formative/diagnostic teaching.

Reflections, Worries, and the Need for Data

Can the ideas described in the preceding section work? Will they? That depends on many things, most of which are systemic and beyond our control.

First, consider the SERP process. Will the San Francisco Unified School District do what we think it needs to do? Ultimately, that's a matter of resources and will. Mixed messages or lack of district support can torpedo our effort before it gets off the ground. Will teachers buy in? That remains to be seen. What we have is a set of hypotheses, grounded in theory, about an approach that might have a chance to work.

Second, consider the Gates project lessons. In all honesty, the support for professional development is small: Without district or school support, a few videotapes are not enough to support teachers in building a supportive community. And, what we have right now is an untested hypothesis – that teaching 20 formative lessons will make a difference, as a

form of professional development. In the spirit of the Hippocratic oath, *primum non nocere* (“do no harm”), I am confident that at minimum, teachers using those lessons will be teaching powerful mathematics. Is teaching 20 such lessons, perhaps repeating the process for a few years, enough to help teachers develop “formative/diagnostic habits of mind?”

These are *lovely* research questions. And I hope to study them like mad. More importantly, the field should be studying such things like mad. The point is that in educational development and research we often design and implement interventions such as professional development in an atheoretical way, without having:

- (i) a theoretical frame (or more) within which the efforts can be contextualized or examined, or
- (ii) systematic data analysis to tell us just what is happening, and allow us to do better next time.

To return to my opening metaphor, professional development – like air travel – is multidimensional, and requires multiple theoretical perspectives. Moreover, making progress on this and other such historically intractable problems requires us to be very serious about gathering data and testing our ideas against the data.

Doing this won’t be cheap or easy – it calls for resources and ingenuity in constructing design experiments (Cobb, Confrey, diSessa, Lehrer, Schauble, 2003) and in data analysis; it calls for approaching these issues theoretically from multiple perspectives and at multiple levels of grain size. However, the cost of not approaching things in this serious and systematic way is the perpetuation of the status quo, or worse.

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The Teachers Institute Approach to Professional Development

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Abstract: *The Yale New Haven Teachers Institute (YNHTI) provides a distinctive, perhaps nearly unique, approach to professional development. It originated in the 1978 as an outreach activity of Yale University to the New Haven Public Schools. For 20 years, it operated almost exclusively in New Haven. In 1998, under the leadership of its founder, James Vivian, YNHTI conducted a National Demonstration Project, and since 2004 has promoted a National Initiative, to spread the Teachers Institute model to other cities, with a focus on school districts with low income demographics. Currently there is a League of Teachers Institutes with Institutes operating in Charlotte, New Castle County, Delaware, Philadelphia, and Pittsburgh. Other locales working towards founding a Teachers Institute include Chicago, Dekalb County GA, Richmond, and the San Francisco area. This article outlines the salient features of the YNHTI.*

Keywords: Math Teachers Institute; Mathematics teacher professional development; outreach activities; *Yale New Haven Teachers Institute (YNHTI)*

The core activity of a Teachers Institute takes place in seminars. Each seminar is led by a faculty member from a participating university or college, with up to a dozen Fellows, teachers from participating school districts. Local seminars will meet on a regular schedule, typically for two hours or more at one time, over a period of months. In New Haven, seminars meet in 12 two-hour sessions, running from March through early July. The National Initiative also runs seminars, for teachers from all participating districts. These National Seminars have preliminary meetings in early May, and their main work is done in a two-week Intensive Session in mid-July.

The distinguishing feature of a Teachers Institute is that, rather than provide evidence of mastery of the seminar topic by examination or other means internal to the seminar, the primary obligation of each seminar Fellow is to write a curriculum unit based on the seminar. This structure obviates questions as to what seminar material is mastered by a fellow, and also the question of whether the seminar affects classroom practice: it automatically does.

The Teachers Institute approach is based on a cooperative partnership between a college or university and a school district. (It is possible to have multiple partners

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on either side of the partnership, but for simplicity we will ignore that possibility here.) Faculty members from the higher education partner contribute their subject matter expertise by offering seminars in relevant topics, and teachers contribute their classroom expertise to create sequences of lessons that incorporate the insights afforded by the seminar. Fellows in a given seminar will typically represent all grade levels, from the primary grades through high school. It follows that seminar themes must be educationally robust: they must have potential for enriching instruction for students of all ages. Seminars can be built around recent advances in a field, especially in science or technology. They may also be built around enduring issues: important perspectives that may escape attention in standard courses, or fundamental ideas that are relatively neglected in existing curricula. The seminars offered in the National Initiative in 2011 were:

The Art of Reading People
Love and Politics in the Sonnet
The Big Easy: Literary New Orleans and Intangible Heritage
Chemistry of Everyday Things
Great Ideas of Primary Mathematics
Organs and Artificial Organs

I have been the main leader of seminars in mathematics for the National Initiative for the past several years. The seminars I have offered in previous years are

The Art and Craft of Word Problems
Estimation
The Mathematics of Wallpaper

A strong feature of a Teachers Institute is the key role played by teachers in all activities. Seminar topics are offered by faculty, but the decisions as to which seminars will run is in the hands of a committee of Teacher Representatives, who canvas their colleagues throughout the district as to which of the proposed topics have the most potential to raise the level of instruction. After seminars are selected, the same committee accepts and vets applications to participate in the selected seminars, and determines seminar membership. Each seminar also has one Fellow who serves as coordinator, ensuring good communication between the Seminar Leader and the Fellows, and especially, that the complex task of unit writing proceeds on schedule, with each Fellow having adequate guidance and support.

In this spirit, the seminars themselves are highly collegial affairs, with regular participation from all Fellows as well as the Seminar Leader. In particular, seminars include time for Fellows to share with each other their plans for their units, and to provide feedback and mutual support for their projects. Discussions initiated during seminar time may well lead to further exchanges between Fellows outside of seminar meetings.

Teachers Institutes are not on their face a low cost approach to professional development. Fellows are paid stipends for successful participation, and seminar Leaders are paid a reasonable salary. Also, Institute seminars do not reach large

numbers of teachers at a given time. Seminars are limited to 12 fellows, and typically fewer than 100 fellows will be participating in seminars in a given year. A natural question to ask, therefore, is, what evidence is there that Teachers Institutes are effective in improving instruction? The main evidence comes from participating teachers, who typically react enthusiastically, even ecstatically, to their experiences in Teachers Institutes. In many surveys over many years in many cities, fellows "consistently rated Institute programs higher than other professional development programs in developing the knowledge, skills, enthusiasm, high expectations of students, and capacities to motivate students that most studies indicate to be central to successful teaching." ([1]) A study ([3]) conducted by Professor Rogers Smith of the University of Pennsylvania, found that the Teachers Institute approach "significantly strengthened teachers in all five dimensions of teacher quality: it helps to produce teachers who really know their subjects; who have good basic writing, mathematics and oral presentation skills; who expect their students to achieve; who are enthusiastic about teaching; and who can motivate children to learn." In my own experience in leading seminars in New Haven and for the National Initiative, the positive, indeed often joyful, reactions of the fellows to their seminars has been a striking and inspiring feature of the work.

In addition to their impact on Fellows, Institute Seminars can have a significant add-on effect. Teachers who develop successful units in key areas may share their insights with colleagues. In several instances, my seminar Fellows from previous years have reported that the new ideas and practices that they developed in my seminar have spread to their whole school.

Also, the units from each seminar are published. At the beginning, they were published in print form, but now also, the National Seminars and many local seminars are available online. These can be viewed by teachers anywhere, and their ideas adopted or adapted as desired. I know that the units of some of my former Fellows have had this kind of impact. It is difficult to know exactly how many students are affected, and to what extent, by the work of Teachers Institutes, but a statistical model developed for the National Initiative suggests that the numbers may be substantial.

Writing a curriculum unit presents a substantial challenge to Fellows. The unit that a first time Fellow writes may be the largest piece of sustained writing that the Fellow has ever done. To guide the Fellow in this substantial endeavor, a careful structure has been elaborated over the years. First is a recipe for the overall form of the unit. A unit should begin with a rationale, stating the broad goals of the unit, and how these goals fit into the fellow's teaching duties, including a summary of the nature of the school where the fellow teaches and the population it serves, as well as district or state expectations regarding the subject of the unit.

Following the rationale is a narrative that discusses in considerable detail the content goals of the unit, and intellectual and practical considerations that must be taken into account to accomplish them. In mathematics, this will probably include a

significant amount of mathematical background that might not be familiar to another teacher who might want to use the unit. The narrative will also discuss sequencing and scaffolding, and what auxiliary ideas will need to be coordinated and brought to bear in order for students to absorb the key ideas treated in the unit. The narrative will also discuss pedagogical strategies the Fellow expects to use to ensure student learning.

The narrative is followed by three or more sample lesson plans illustrating the treatment of some key topics, and annotated bibliographies from the Fellow's research: the sources consulted to learn the relevant material and to produce the unit, a reading list for students, and sources of classroom materials.

Besides the guidance of overall form, a carefully sequenced schedule of steps toward the final unit has evolved, with substantial support available at each step.

The writing process begins with the prospectus, in which a Fellow attempts to articulate his or her main goals, and outlines some strategies to attain them. The prospectus forms the basis for one-on-one discussions with the Seminar Leader, to review the appropriateness, coherence, focus and scope of the goals and means described in the prospectus. These discussions result in a refined, focused, and probably feasible plan. If s/he has not already done so, the Fellow can begin writing at that point. In addition, the Fellow will probably present the draft plan for the unit in the seminar, and obtain feedback and suggestions from the other Fellows. This input is often incorporated into the draft plan.

The next main stage is the first draft, which is due midway in the course of the seminar. The first draft consists most importantly of the narrative, which is typically the most challenging part to write. The detailed lesson plans and the bibliography, and even the rationale, may wait until later. The first draft forms the basis for a second set of interviews between the Fellow and the Seminar leader. The Leader will offer fairly extensive remarks, both on the content and organization of the draft, especially of the narrative, and on specific issues of style.

The Fellow takes the Seminar Leader's comments and incorporates them into a second draft. The second draft is more ambitious than the first in that it should be an essentially complete version of the unit, with all the constituent parts in more or less complete form. The second draft is then reviewed by the Leader, who again will make suggestions, this time probably concentrating less on overall organization, which should have been largely addressed in the discussion of the first draft, and more on local issues of style and, in the case of mathematics units, specifics of logical development. The comments on the second draft will then be used by the Fellow to produce a third draft. Normally, the third draft is essentially the final version, and will need only minor changes, or perhaps none at all, to be published as part of the collection of units from the seminar. Until recently, publication meant the production of physical volumes collecting all the units in the seminar, with an

introduction and summary written by the Seminar Leader. Now, publication of units from the National Seminars is online. Units from recent National and local seminars can be found at

<http://teachers.yale.edu/units/index.php?&skin=h>

Articles of Understanding

The National Initiative has formulated "Articles of Understanding" that characterize the Teachers Institute approach to professional development. We give brief summaries of the articles here. These articles are spelled out in [1], which has been the main source for this note.

Article 1: Partnership. A Teachers Institute links an institution (or institutions) of higher education (the *higher education partner(s)*) to a school district (or districts) in which a significant portion of students come from low-income communities. The Institute is an independent unit within (one of) the higher education partner(s), which assumes full administrative and financial responsibility for the Institute.

Article 2: Participants. Teachers who participate in an Institute become Fellows in its seminars. A group of Teacher Representatives are selected from the Fellows. Faculty members at the partner university serve as Seminar Leaders and/or on a University Advisory Council to the Institute.

Article 3: Direction. The Institute should have a full-time Director, who serves as convener, administrator, liaison between the partner school district(s) and higher education partners, and as fund raiser. The Director is an employee of the higher education partner that houses the Institute.

Article 4: Leadership of Teachers. Participating teachers, through the Teacher Representatives, play a major role in planning organizing, conducting and evaluating the programs of the Institute. They seek input as to desirable seminar topics, select seminars to be offered, recruit and select Fellows for the seminars, and serve as Seminar Coordinators.

Article 5: Faculty Role. Faculty in the partner university offer seminars, advise in the selection of seminars, and participate in reviewing the results of each year's activities.

Article 6: Seminars. Seminars comprise approximately 12 Fellows and a Leader. Seminars are intensive collaborative, collegial investigations of broadly defined topics with robust educational potential. Seminars should hold at least 12 two-hour meetings over a period of approximately three months. During the course of the seminar, each Fellow should produce at least two drafts of their proposed curriculum unit, based on the theme of the seminar.

Article 7: Curriculum Unit. The curriculum unit is the means by which a Fellow articulates what s/he has learned in the seminar, prepares to transfer that learning to the classroom, and communicates that learning to other teachers. Each unit consists of between 15 and 30 single-spaced pages, and includes the rationale and objectives of the unit, an exposition of the material to be presented in the classroom and of the pedagogical strategies to be used, several sample lesson plans, and an annotated bibliography.

Article 8: Collaboration. The melding of subject matter with pedagogical strategies and procedures is fundamental to the Institute approach, and is essential to the collegiality on which an Institute is founded. The Seminar Leaders are primarily responsible for presenting the disciplinary content of the seminar, along with any pedagogical principles that inhere in that content, while the Fellows, individually and collectively, are responsible for bringing that content to bear in their classrooms in ways that will motivate active learning by their students.

Article 9: Collegiality. Seminar Fellows and Leaders are considered professional colleagues cooperating collegially to produce good educational outcomes, based on the curriculum units produced by the Fellows.

Article 10: Eligibility. Any teacher in a partner district whose teaching assignment is related to a seminar being offered, and who can incorporate the theme of the seminar in a curriculum unit to be used in the following year, is encouraged to present a proposal to be a Fellow in that seminar.

Article 11: Remuneration. In recognition of the intensive, demanding and professionally significant nature of the work of Seminar Leaders, they will be remunerated for their participation in seminars. The participation of Fellows will also be provided with a stipend and/or honorarium on completion of their unit and all Institute requirements.

Article 12: Long-Term Commitment. The founding of a Teachers Institute presupposes a long-term partnership between the higher education partner(s) and the partner school district(s).

Article 13: Funding. Both the higher education partner(s) and school district(s) are committed to provide sufficient ongoing financial support to the Teachers Institute.

Article 14: The League. The Teachers Institutes of the National Initiative will have an explicit and visible relationship. Their subscription to these Articles of Understanding should be documented in annual reports.

Article 15: Evaluation. Teachers Institutes undertake at their own cost annual reviews of and reports on their progress, in cooperation with the Yale National Initiative. They will submit annual financial and narrative reports, both to the National Initiative and to relevant funders.

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- [2] Rogers M. Smith, To Strengthen Teaching: An Evaluation of Teachers Institute Experiences, 2009.
- [3] Rogers M. Smith, To Motivate My Students, An Evaluation of the National Demonstration Project of the Yale-New Haven Teachers Institute, 2004.

Teachers as Stakeholders in Mathematics Education Research

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Abstract: *This paper states three claims dealing with the relationship between mathematics education researchers and mathematics teachers: (1) Mathematics education research is a highly diverse field; (2) Teachers have various roles as stakeholders in mathematics education research; (3) Regarding teachers as stakeholders in mathematics education research affords reflecting some (fruitful) „cultural differences”. The paper claims the necessity to regard researchers as key stakeholders in practice, and teachers as key stakeholders in research.*

Keywords: Mathematics education researchers; Researchers as stakeholders; Mathematics teacher professional development; Practice

Introduction

To organize a conference on the issue of “Teachers as stakeholders in mathematics education research” is taking up an important challenge. It is an ethical responsibility of a scientific community and at the same time a wise strategy to raise questions like: How does the scientific community’s knowledge get known, used and reflected by relevant people and institutions? What can be done by researchers apart from writing papers and giving talks (predominantly within the scientific community), and from teaching classes of student teachers and offering professional development courses? (Krainer, 2011)

There have been efforts by individual researchers and groups to address this issue (e.g., Bazzini, 1994; Steinbring, 1994; Lin & Cooney, 2001; Krainer & Llinares, 2010; Kieran, Krainer, & Shaughnessy, 2013). Despite these efforts and continuous claims of how important teacher-researcher collaboration role is, teachers are most often seen as more or less passive recipients of researchers’ knowledge production and sometimes as a means to produce knowledge.

What is missing, in particular, is a systematic effort by the scientific community to analyse the potential role of teachers in research and its benefit for teachers and researchers. In order to understand the potential role of teachers, a first step, the diversity of mathematics education research needs to be sketched.

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Mathematics education research is a highly diverse field

Mathematics education deals with the learning and teaching of mathematics. Therefore, at least students, (prospective and practising) teachers and teacher educators (the latter are often also the researchers, see e.g. Adler et al., 2005) are relevant people. In addition, also the relationship between students and teachers as well as teachers and teacher educators might be a focus.

Thus, at least big five research foci are to be taken into consideration:

Student(s)

Student(s) – teacher(s)

Teacher(s)

Teacher(s) – teacher educator(s)

Teacher educator(s)

In each case, research might investigate students, teachers and/or teacher educators' beliefs, their knowledge or their practice, or combinations of these.

The learning of teachers, including all formal kinds of teacher preparation and professional development as well as informal (self-organized) activities, is only one domain of mathematics education research. One part of the diversity of research is based on the diversity of formats of teacher education. Even if we reduce this issue to teacher education for practicing mathematics teachers, the formats of activities – and thus of related research – are highly diverse. They include, for example: formal activities led by externals or informal and self-organized ones; single events or continuous and long-lasting programmes; small-group courses or nation-wide mathematics initiatives; heterogeneous group of participants or a mathematics-focused school development programme at one single school; obligatory participation in courses or voluntary engagement in teacher networks; focus on specific contents or on more general issues; theory-driven seminars at universities or teaching experiments at schools; focus on primary or secondary schooling; teacher education accompanied by extensive research or confined to minimal evaluation (see more detailed in Krainer, 2008a).

Another approach to demonstrate the diversity of research – focusing only on the subfield of teacher education – is to regard the diversity of goals and formats of (teacher education) research. It is a challenge to investigate one teacher's way of teaching in one class during a short period of time. However, it becomes much more complex if we are dealing with more classes of one teacher, or with more teachers, or with investigating teacher change on the basis of an intervention (pre-post-comparisons etc.), or if we also investigate students' change or the interaction between students and teacher. The researcher might be an external university staff member, a school internal expert or the teacher him- or herself.

Table 1. Levels of teacher education

	Number of M teachers	Relevant environments (in addition to mathematics teacher educators)	Major mathematics education research focus on ...
Micro level	1s	Students, Parents, ...	Individual teachers, Teams
Meso level	10s	Colleagues, Leaders, ...	Communities, Networks, Schools
Macro level	100s	Superintendents, Policy makers, ...	Districts, Regions, Nations

In addition, we also have to look at the diversity of interests. Concerning the three levels, quite different people are interested in the impacts of teacher education initiatives (Krainer, 2008): in the case of single classrooms, the students and their parents are the most concerned environments; in contrast, superintendents and (above all) policy makers are more interested to get a whole picture over all classrooms in a country. For example, PISA plays a major role for nations' system monitoring of mathematics teaching, but not so much for individual teachers and parents. They are more interested in the learning progress of their own students. Schools as organizations or networks of dedicated teachers lay somewhat in between. On the one hand, a school is important for teachers and parents since this organizational entity forms a crucial basis and environment for students' learning; for example, this includes important feelings of being accepted, autonomous, cognitively supported, a member of a community, save, taken serious etc. On the other hand, reformers need to see schools as units of educational change since they cannot reach teachers and students directly. All in all, each of the three levels is important and they should be regarded as closely interconnected.

All in all, mathematics education research – in particular when dealing with teacher education – is highly diverse. It has become clear that also teachers' roles can be diverse. The next chapter elaborates this more closely.

Teachers have various roles as stakeholders in mathematics education research

As mentioned above, a systematic effort by the scientific community (societies, commissions, universities, research groups, etc.) is needed to analyse the potential role of teachers in research and its benefit for teachers and researchers. The question is urgent since the increasing economic

pressure on research accompanied by a citation-index-driven accountability will lead to an intensified focus on paper production (in high ranked journals); less efforts are made to “go the complex way” by writing papers together with teachers (in equally important but – from an internal promotion view within the scientific community – less valued sources). To build the bridge from the teaching profession to the scientific community, well-developed organizations like NCTM with high-quality publications (e.g., Handbooks, NCTM-standards) are important. Another strategy is that teacher unions (like the LCH in Switzerland) employ scientists in order to build bridges to the scientific community.

There is a tradition to view teachers as experts (e.g., Bromme, 1992). In particular, they are regarded as researchers (e.g., Stenhouse, 1975; Altrichter & Posch, 1990 – English version: Altrichter, Feldman, Posch, & Somekh, 2008; Elliott, 1991; Crawford & Adler, 1996; Jaworski, Fuglestad, Bjuland, Breiteig, Goodchild, & Grevholm, 2007) and reflective practitioners (e.g., Schön, 1983). Intervention research with teachers as partners and action research by teachers or teacher educators is becoming more prominent in mathematics teacher education, for example: editorials and papers in JMTE 6(2) and 9(3), and in ESM 54(2-3); chapters in the PME-Handbook (e.g. Llinares & Krainer, 2006), chapters in the “International Handbook of Mathematics Teacher Education” (e.g. Benke, Hospesová & Tichá, 2008) and in the “Third International Handbook of Mathematics Education” (e.g. White, Jaworski, Agudelo-Valderrama & Gooya, 2013), and in the International Encyclopedia of Education (e.g. Krainer, Chapman & Zaslavsky, 2012). There is also an increase in studies on teacher educators’ learning (see e.g., Jaworski & Wood, 2008; Even & Krainer, 2013). Some researchers claim that they learned enormously from teachers, and even reflect this in papers.

However, research and policy often seem to focus primarily on teachers’ weaknesses. For example, often the immediate reaction to bad results in comparative studies is to start professional development initiatives for teachers as if it were the teachers only who need to change. Less attention is paid to the efficacy of the support system for schools, to the teacher education system, to teachers’ general conditions and reputation etc. Such reactions indirectly blame teachers and – at the same time – they are unsatisfactory starting points for reform initiatives. If research and policy do not admit that the whole system (including policy, teacher education and research) needs to change, the phrase “teachers are key agents of change” is a threat rather than an indication of their important role.

We need to be aware that research can have hindering or demotivating effects to teachers. For example, studies in mathematics education which emphasize on teachers’ low mathematical competencies, their “monoculture” regarding teaching methods or their unwillingness to inform themselves about new research results, have effects that should not be underestimated. It seems more viable to highlight the complexity of teachers’ task and also to report strengths and opportunities. It should also be taken into account that teacher educators are co-producers of this lamentable situation by being role models in teacher education courses. Likewise researchers are responsible for offering viable opportunities that encourage teachers to get interested in research.

It is not surprising to hear critical assessments of mathematics education research with regard to practitioners' learning. For example, Ponte (2009, p. 102) indicates the "view of the 'deficient' teacher, so common in the research literature". In contrast to teachers' lack of knowledge etc., often researchers are seen as the ones where the knowledge is situated. This characterizes a view where knowledge transfer is a one-way street from researchers to teachers. To put it more crudely: Teachers have problems, researchers have solutions; and the latter (and we might include representatives of educational policy and administration) also know the way(s) to disseminate innovations to teachers by means of curricula, standards, tests, material, lectures, seminars etc. This is the classical Research-Development-Dissemination (RDD) model of innovation whose limitations are shown all over the world.

In order to criticize this view, Schön (1983) introduced the term "Technical Rationality" into the educational discourse. It follows three basic assumptions:

- There are general solutions to practical problems.
- These solutions can be developed outside practical situations (in research or administrative centres).
- The solutions can be translated into practitioners' actions by means of publications, training, administrative orders, etc.

Technical Rationality causes a hierarchy of credibility, expressing a genuine mistrust of practitioners: Teachers work at a "low level of theoretical knowledge and are merely applying what has been predefined in the academic and administrative power structure above them" (Altrichter et al., 2008, p. 270). In turn, this evokes resistance by teachers, opposition against reform and a genuine mistrust of researchers (and of education policy and administration people). It is a vicious circle.

In contrast to Technical Rationality, "Reflective Rationality" (see e.g., Posch, 1996; Altrichter et al., 2008, p. 270) follows three very different assumptions:

- Complex practical problems require particular solutions.
- These solutions can only be developed inside the context in which the problem arises and in which the practitioner is a crucial and determining element.
- The solutions can only rarely be successfully applied to other contexts, but they can be made accessible to other practitioners as hypotheses to be tested in practice.

These assumptions imply new types of communication among practitioners and new types of communication between practitioners and researchers (some people speak of theorists). The new communication needs to be built on symmetry rather than on hierarchy – both teachers and researchers have problems (some prefer the term challenges); and both need to find solutions, internal to their practice, but a critical stance and external views can be of support in defining the problem, in finding solutions or better ways to cope with the situation.

Reflective Rationality regards teachers (practitioners) as important producers of knowledge and “practical theories” (see Altrichter et al. 2008, p. 64-72). This production of knowledge can be done with or without external interventions. Regarding the latter option, teachers investigate their own practice in order to improve it (in the sense of action research, see e.g., Altrichter et al., 2008). Teachers doing action research might be supported by other persons, but it is the teachers who decide which problem is chosen, which data are gathered, which interpretations and decisions are taken etc. Action research challenges the assumption that knowledge is separate from and superior to practice. The production of “local knowledge” is seen as equally important as general knowledge, “particularization” (e.g., understanding a specific student’s mathematical thinking) as equally important as “generalization” (e.g., working out a classification of typical errors).

The stakeholder approach

In the 1980’s, an interesting change of paradigm was taking place in conceptualizing the role of management with respect to its environment (in particular in the USA). The traditional view was the shareholder approach which regarded it the duty of management to fulfil the interests of the shareholder only. Basically in order to prevent having poor social performance hurt the company financially, the management aimed at satisfying clients, consumers, society etc. by specific strategies (e.g., public relations). In contrast, Freeman (1984) and others developed a stakeholder approach, defining “stakeholder” as “any group or individual that can affect or is affected by the achievement of a corporation’s purpose” (Freeman, 2004, p. 229). The approach dealt with the practical concerns of managers – “how could they be more effective in identifying, analysing and negotiating with key stakeholder groups?” (p. 230). The stakeholder idea is connected to ethics and values, which are regarded as equally important as the business itself.

Regarding researchers as those having most expertise in research (theory, methodology etc.) and thus heavily setting the trajectories of research, they nevertheless are assumed to form their decisions not only for the sake of the scientific community but more broadly for society as well. Of course, other persons, groups and social systems also have a stake in the development of students’ knowledge: for example, parents, principals, superintendents, mathematicians, teacher educators, educational publishers, test developers, companies, (education) policy-makers, and even the whole society can be regarded as “stakeholders” of the (joint societal) “enterprise” to promote students’ mathematical knowledge. They all have effects on students’ knowledge and at the same time they are affected by their knowledge or lack of knowledge.

Research shows that the “myopic institutions theory” – claiming that companies that invest in stakeholder management will be penalized by investors who are only interested in financial returns – gets little support (Freeman, 2004, p. 237). In other words, it does not hurt a company to look beyond shareholders. In other words: Looking at the whole system (of interests) is beneficial for all parts of a system aiming at sustainable development and peace.

How might a scientific community reflect on its relationship to practitioners? One strategy is to reflect upon the relationship to those practitioners (teachers) interested in research not participating in meetings of the scientific community. A second strategy is to reflect upon situations where

members of this community act themselves as practitioners (teacher educators). A third strategy is to reflect upon situations where teachers themselves investigate their practice (see e.g. Krainer, 2011).

The question how intensively researchers regard teachers as stakeholders is an expression of the – intended and/or lived – relationship between teachers and researchers. This means that our view on „teachers as stakeholders“ is about „us“, about our beliefs and roles, about our understanding of „research“.

Consequently, reflections before starting a MER project should include at least the following two questions:

How deeply do we expect teachers (and other stakeholders) to have an interest in the process and the result of the project?

How much could/should the project affect teachers (and their practice), and how much could/should teachers (and their practice) affect our project?

Intensifying collaboration with teachers and regarding them as key stakeholders in mathematics education research does not at all mean that teachers and researchers have the same backgrounds, interests, roles etc. The following chapter reflects “cultural differences” that need to be taken into consideration when regarding teachers as key stakeholders, in particular in the context of collaborations between teachers and researchers.

Regarding teachers as stakeholders in mathematics education research affords reflecting some (fruitful) „cultural differences”

Collaborations between teachers and researchers are influenced by the different cultures they stem from. In the following, “cultural differences” are sketched in order to highlight possible dimensions which need to be taken seriously when negotiating interests.

Growth: In general, teachers aim at fostering students’ and both their own (affective, cognitive and personal) growth and those of colleagues at their school, while researchers – in addition to fostering teachers’, teacher students’ and their own growth – put an emphasis on contributing to knowledge growth of the scientific community.

Knowledge: In general, teachers aim at generating local knowledge for people involved in the particular context, while researchers aim at generating global knowledge in order to generalize their findings.

Transfer: In general, teachers aim at applying new knowledge in their practice, while researchers aim at publishing their findings, in particular putting an emphasis on its implications for theory.

Time to reflect: In general, teachers don’t have much time to reflect before taking decisions in their practice but have to react immediately, while researchers have time to analyse (parts of) lessons

(e.g. watching the video again and again) in order to understand the rational and implications of decisions taken.

Sharing knowledge: In general, teachers – given they find time for that – share their knowledge with colleagues orally, while researchers generate and share written artefacts.

Evidence: In general, teachers refer to past experiences by memory not based on data, while researchers base their arguments on (systematically gathered and analysed) present data.

Drawing conclusions: In general, teachers aim at working out practice-relevant assessments in the sense of consequences for their work (things to change etc.), while researchers aim at focusing on theory-driven interpretations (based on accurate descriptions which often miss in teachers' case).

Field approach: In general, teachers – having responsibility for students' learning – are and feel heavily involved in their particular context (involved nearness), while researchers can approach the context more neutral (critical distance).

Attitude: In general, teachers overestimate the immutability of general conditions that frame their work and thus – taking into consideration these constraints – have a rather optimistic view concerning their impact on students' learning, while researchers underestimate the general conditions that frame teachers' work and thus – viewing much more scope of freedom and flexibility for teachers to act – have a rather sceptical view concerning teachers' impact on students' learning.

Of course, these “cultural differences” can vary from context to context and might even be not observable or even be switched. However, the dimensions are a starting point to reflect on these potential differences. Often, progress might be achieved by looking into other's domain: for example, related to sharing knowledge, it would be important to teachers to systematically gather data in order to be able to discuss the situation on the basis of written artefacts. In contrast, researchers might realize the power of sharing experiences orally with teachers in order to get an understanding of relevant information not being gathered so far.

These “cultural differences” are a good starting point for negotiating interests and values, and for building trust between teachers and researchers. Respecting these “cultural differences” and even using them as an advantage for joint growth seems to be a powerful window of opportunity to foster knowledge production for all people concerned.

Final comments

The notion of “teachers as stakeholders in mathematics education research” is marking a movement from regarding teachers as more or less passive recipients of researchers' knowledge production or as a means to produce knowledge towards regarding teachers as producers of knowledge, relevant to them but also to the scientific community.

In order to promote knowledge production at a larger scale, researchers need to support teachers' knowledge production at different levels. However, they can't transmit knowledge or theories

directly to the practitioners; they can only offer them environments in which they are able to further develop their existing knowledge and belief system. Researchers and teachers' knowledge and (practical) theories can have nearly no overlap, or alternatively, a large one (with many positions in between).

It seems worth to reflect on the following three hypotheses:

The more researchers regard practitioners as stakeholders of research, the more their knowledge and theory bases will overlap.

Good collaboration and mutual trust between them increases the further development of both parties.

Since researchers are better internationally and thematically organized (in particular based on written artefacts and conferences), they should assume the responsibility of taking serious steps to promote the negotiation process (e.g., Krainer, 2008), based on both parties' strengths and as a two-way-street.

The ideal way would be to regard researchers as key stakeholders in practice, and teachers as key stakeholders in research.

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Teaching and learning mathematics with Math Fair, Lesson Study and Classroom Mentorship

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Abstract: *For more than a decade, researchers, math educators and professional developers from the Galileo Educational Network (Galileo) in the Faculty of Education at the University of Calgary, to which the two of us are associated, have worked to improve the teaching of mathematics. Our focus has always been twofold: to improve teacher knowledge of mathematics and the pedagogy of teaching mathematics. We report on the extensive work we have conducted with teachers with lesson study, classroom mentorships and math fairs.*

Keywords: Lesson study; Math fairs; Math teacher professional development; Galileo Educational Network

Introduction

Initially encouraged by the findings of the Third International Mathematics and Science Study (Institute of Education Sciences, 1995), we started our first Lesson Study. We sought and acquired external funding. We invited mathematicians from the Pacific Institute for the Mathematical Sciences (PIMS) to join our efforts. We extended an invitation to teachers from the schools in which Galileo professional developers were working. Monthly sessions with teachers, mathematicians, mathematics educators and researchers all focused on improving mathematics learning and teaching were followed by job-embedded professional development for teachers. We worked with teachers in the context of their own classrooms providing them with support by teaching alongside them,

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videotaping their instruction for later examination and discussion and providing them timely, effective feedback on their instruction.

Initially, we began with only the findings from Institute of Education Sciences (1995), knowing that something needed to change in order to bring about the stronger mathematical reasoning. Through personal communications in 1999 with James Hiebert, researcher from Institute of Education Sciences (1995) videotape study, we were encouraged to contact Clea Fernandez who was forming a Lesson Study group in the United States. While we built on many of the ideas and approaches from Fernandez and Yoshida (2004), we also modified our approach to Lesson Study to adapt to the needs of our teachers. Like Fernandez and Yoshida, teachers met to collaboratively plan lessons; however, knowing that the majority of our teachers did not have enough mathematical knowledge for teaching we always included at least one, and frequently more than one, PhD mathematician, mathematics educators and researchers in our endeavours to ensure our planning was rooted deeply in the discipline of mathematics. Although our funding allowed us to provide teachers with monies with release time to meet during class hours, we were unable to also fund teachers to obtain teaching release time to observe lessons being taught. That said, we were able to provide teachers with a combination of mathematicians, mathematics educators and/or professional developers to work alongside them in their own classrooms as they tried out new instructional strategies. To provide teachers the opportunity to learn from other teacher's lessons we videotaped the teachers. Videotapes were viewed and discussed during a portion of our group meetings.

Our Lesson Study has never been devoted entirely to lesson planning. We always split our time between planning and learning mathematics for teaching as many teachers

in Alberta (and Canada) lack sufficient background and understanding of mathematics (Friesen, 2005). In this way, the teachers in Alberta are not unlike many teachers in the United States.

In Liping Ma's (1999) groundbreaking study she identified a discrepancy in the mathematical knowledge between teachers in the US and China. Teachers from China have less education than their U.S. counterparts, yet they have a better understanding of mathematics for teaching. Unsurprisingly, the quality of mathematics teaching was dependent on the teachers' mathematical understanding. Ma called for a more connected longitudinal concept development form of teaching mathematics.

Ball et al., (2005) observed that of mathematical understanding of many U.S. teachers is "dismally thin" (p. 14). They argue that rather than more advanced undergraduate mathematics classes, teachers would benefit from knowing more mathematics for teaching. Yes teachers need to know the concepts and procedures they teach: fractions, functions, factoring, symmetry, etc. But to extend this knowledge into their classrooms, teachers need a different type of mathematical knowledge for teaching for planning, implementing, evaluating, and assessing student work. Beyond recognizing student errors, teachers need to be able to pin point the misconception that resulted in the misunderstanding. Effective mathematics teachers need to engage these (mis)understandings and move student understanding into the discipline of mathematics (Fuson, Kalchman, & Bransford, 2005). Being able to explain *why* and the *meaning* of mathematical concepts require much more than being able to *do*.

Learning the *why* and the *meaning* of mathematical concepts is extremely difficult when people have been taught mathematics as sequence of rote facts and procedures to be

remembered, recalled and regurgitated rather than connected concepts to be understood requiring procedural fluency and adaptive reasoning; developing strategic competence and a productive disposition (Kirkpatrick et al., 2001).

The practice of remember, recall and regurgitate has lead to an identifiable teaching script, “consistent with the belief that school mathematics is a set of procedures” (Stigler & Hiebert, 1999, p.2). This teaching script, referred to as the North American teaching script (Stigler & Hiebert, 1999) involves teachers demonstrating a procedure and students repeatedly practicing the procedure with similar questions. Research has shown that this script is ineffective (Stigler & Hiebert, 2004; Institute of Education Sciences, 1995; Institute of Education Sciences, 1999; Institute of Education Sciences, 2003) leading to what Perkins (1992) calls fragile mathematical knowledge.

Each successive generation of teachers who learned mathematics in just this way have come to believe that mathematics as a discipline is a set of procedures. This belief divorces math learning from the “community of relations” (S. Friesen, Clifford, & Jardine, 2008, p. 118) in which the discipline of mathematics resides. Changing teachers’ practices and beliefs about the nature of mathematics has been our greatest challenge.

That’s A Good Problem

In 1999 a group of mathematicians, math educators and teachers, supported by PIMS, Mt. Royal College and the Galileo Educational Network, started to address the problem of mathematics learning and teaching in K-12 in Alberta. While we knew that policy work was needed, we took a different approach. We started our work at the level of the classroom starting an initiative which we called *That’s A Good Problem*. This

initiative provided teachers, students and parents with an opportunity to engage with mathematics, increasing the mathematical understanding and competence of teachers, providing opportunities for deep engagement with mathematics and providing teachers with the opportunity to work with and learn from mathematicians and math educators within the context of their own classrooms.

Schools are invited to send a team of four or five teachers to a half-day professional development day. The focus of this meeting was on: teaching mathematics through math explorations and investigations by working through a number of math explorations and investigations.

Mathematical investigations and problems were created or provided by research mathematicians and math educators. Each of the investigations or problems had particular characteristics in that they:

1. Began with a "story" (i.e., they were situated in a meaningful context)
 2. Allowed group work, but encouraged individual effort.
 3. Required that students work with mathematical ideas in an active manner.
 4. Could be successfully explored at many levels.
 5. Permitted innovative solutions by students.
 6. Included a rapid evolution from the simple to the profound.
 7. Exposed the frontiers of knowledge when exploring ideas.
 8. Dealt with fun and important, useful mathematics.
 9. Ensured participation requires the communication of original thought.
 10. Provided opportunities for interpretation, multiple correct solutions.
- (Friesen & Stone, 1996)

The magnitude of the required change for teaching these explorations and investigations was difficult for teachers to envision let alone implement in their classrooms. Two colleagues from a neighbouring university were introducing their math students to good problems through an activity which they called Math Fair. We decided

to introduce the teachers we were working with to ideas from Math Fair as a way to introduce good problems into their classroom practice.

Math Fair is a mathematical problem solving fair developed by Dr. Andy Liu and Dr. Ted Lewis, both PhD mathematicians, to bring students closer to the discipline of mathematics (GENA, 2008b; Lewis, 2002). Unlike the familiar science fair, math fair was designed to involve all students in non-competitive, student-led, active problem solving activity. Math Fair problems are rich, good problems which require students find connections and patterns, make conjectures and develop mathematical reasoning. After trying a number of different problems, teams of two children choose and become an expert of one problem. They learn how to give hints and extensions without revealing the solution. At the Math Fair event, students coerce and coach invited adults and peers to solve their problem. A successful Math Fair requires rigorous mathematical work.

We have found that Math Fair is a small enough parcel for teachers to bite into and try out a different teaching script. For us, Math Fair became the crack that helped teachers catch a glimpse of a different way to teach good math problems and launching point to explore math concepts and connections.

Our mentorship for Math Fair still follows the same format as when we first began with *That's A Good Problem* which has since formed the basis of our current version of Lesson Study. In our first meeting, teachers who are interested, come together to solve good problems and learn what is required to host a successful Math Fair. We provide teachers with information and images of past successful Math Fairs. Once the logistics of Math Fair have been discussed we explore a few Math Fair problems together. We place the teachers in the exact space we hope their children encounter.

Math Fair problems require mathematical thinking and reasoning. We do not provide solutions to the problems. Many teachers find this aspect of good problems somewhat unnerving as most are unfamiliar with having to justify a mathematical solution to a problem. This is often uncharted territory for teachers. However, we encourage teachers to come forward and present their solutions. We teach into the space that their solutions open for us. In this way, we demonstrate for the teachers the ways in which robust, problem solving activity unfolds.

Our next step in Math Fair is to go into the teachers' classrooms where a mathematician and a math educator or professional developer presents problems to the students. Students are enticed to jump into the problems. For most students, this way of approaching problems is unfamiliar. Used to being carefully led through a procedure which leads to a correct solution, the students exhibit many of the same behaviours of their teachers. They want the assurance that there indeed is a unique solution and in time, we will reveal the answer. However, committed to immersing the students in robust mathematical thought and reasoning, that is not dependent on flipping to the back of the book and identifying the correct answer, we persist by traversing the mathematical territory with them showing them where they have already travelled and identifying possible next landmarks. We provide many words of encouragement and leave hints about how they might get the problem to yield more of its secrets. Students experience a range of emotions when tackling difficult mathematical work from frustration to elation. When a student has found a solution we ask them to explore alternate solutions or provide them with an extension to keep them working on the problem and exposing the

elastic nature of good problems. The rich elasticity of the Math Fair problems provides a course of action for differentiated learning.

Once most of the students have found a solution to the problem we get them to bring their understandings forward to the class. Together we explore the innovative solutions students have discovered. Then we follow with a discussion about the mathematics we have been investigating.

We then leave the teachers for a few weeks or months depending on their time frame to work on the problems with their student. Teachers are encouraged to explore with their students to find the paths. We always remain in contact by phone or email for students and teachers alike.

Our next visit to the classroom occurs once students have chosen their problem to present at the Math Fair. We introduce students to a formative assessment instrument, a bulls-eye rubric that we have developed, tested and modified (GENA, 2008a), to use as they are working on their problem. The top half of the bulls-eye is based on Kilpatrick et al.,'s (2001) five intertwining strands of mathematical proficiency: adaptive reasoning, procedural fluency, conceptual understanding, productive disposition and strategic competence. The lower part of the rubric is dedicated to the students' hints and extensions, coaching ability and their display. For a successful Math Fair, students need to be proficient, at the centre of the bulls-eye, in all areas of the rubric.

Teachers are often surprised at students' ability to engage with the math investigations. Students are often surprised that they have the ability to assist an adult solve their math problem.

I enjoyed the math fair because it was fun solving the difficult problems. My mom thought they [people] were confused on jumping chips and my mom got frustrated

and skipped jumping chips. I felt good because we helped them [parents] instead of them helping us. Math can be fun, exciting and interesting. I would like to have a math fair because we can do better in math and want to do math. We did this because we wanted to see how our parents solve the problems, because they solve them in a more advanced way. – Joel

The math fair was a success because we all worked together. I enjoyed making a problem and working in a group. It was hard for my parents to figure out the problem. Helping my parents was good because then it would be easier to make them finish the problem. We should have a Math Fair every year so other people and our parents can learn more math and to give us different ways to do math. It also shows us math is fun and to improve math. Math can be exciting and we can be better problem solvers. – Emmett

I feel math is fun again. I went with my uncle and he thought it was really nice. I felt really smart helping my uncle. At first he didn't get it then I told him to read it again. I would want a math fair every year because we can see how smart our parents are. – Sarah

I think the Math Fair was fun because I have all the games to myself. I enjoyed when I made the hint cards and made the heads and tails for our game. My mom was confused of my game and when she finished playing she went to Randy's house. When I helped my mom she got better luck of playing. I like the Math Fair because our brain gets smarter and our parents too. Doing different ways to do math is fun. I want to do a Math Fair each year because we will be better at math. Math can be exciting and I can be better at math. – Chi

After teachers have hosted a Math Fair, we follow up with another group session with the teachers where we discuss their learning from the Math Fair experience. Teachers are often encouraged by the positive energy and mathematical insights generated in Math Fair. Math Fair provides images of what working with math differently may look and feel like.

For some teachers that is as far as they are willing to travel. For them, Math Fair becomes a one of event, an add-on to their 'real work' of teaching students mathematical procedures. Their beliefs and practices of mathematics remain unmoved, their teaching script unchanged despite the changes in learning they have observed in their students. For others Math Fair gave them a glimmer of possibilities and provides an opening for

change. These teachers are ready to transition their mathematical experiences from Math Fair into student learning and our Galileo Lesson Study. We have found that a combination of Math Fair, Lesson Study and strong classroom mentorship is effective in helping teachers develop stronger instructional practices for teaching mathematics.

Beyond That's A Good Problem: Galileo's Lesson Study

Our Galileo Lesson Study addresses both knowledge of mathematics and knowledge of mathematics for teaching. Our research has shown that mentorship is absolutely integral to supporting teachers in their efforts to improve their practice. When teachers were ready, we mentored teachers within the context of their own classrooms. We worked with the teachers to design lessons, teach alongside them at times and provide them with timely, specific feedback on their instruction. We specifically looked for student understanding and helped teachers coach their students through problems encouraging them to dig deeper into mathematics and to assist them to teach into the various solutions students presented to the class. We found that we needed to scaffold the teachers learning in this way to have them take on rich, rigorous mathematical problems and stay true to the mathematical reasoning and problem solving needed for mathematical proficiency. Our research indicates that we were making headway with teachers shifting their teaching script.

Unfortunately, a few years ago we lost our funding. While we were able to continue with Math Fairs, as schools were able to afford the small price tag for our externally subsidized Math Fairs, and we were able to provide monthly Lesson Study meetings after school hours, along with PhD mathematicians from Mount Royal College

and the University of Calgary but were no longer able to provide the accompanied mentorship in the teachers' classrooms. Our research has shown that the classroom mentorship was a necessary component of our Lesson Study. Lesson Study, without the classroom mentorship was starting to yield less robust mathematical instruction. In an effort to address this matter we began working with video exemplars from a variety of sources.

A Problem With Transfer of Professional Learning: A Case Study of Area of a Triangle

During one Lesson Study we watched the video “Can you find the area?” (Takahashi, 2002b). In Takahashi's lesson, students used geoboards and dot paper of the same unit size. Students used elastics to create the exact right-angled isosceles triangle shape Dr. Takahashi requested on the geoboard. They then recreated the exact shape on the dot paper. Before moving on, Dr. Takahashi invited two students with different sized triangles to bring their work forward. Together, the class learned which was the accurate size. With an exact geometric right-angle isosceles triangle, students were then asked to find the area. A right-angle isosceles triangle lends itself to accurate counting of the squares and half squares, although, Dr. Takahashi gave his students the opportunity to make that discovery themselves. With successive exercises, the shapes of the triangles evolved and Dr. Takahashi lead the students to discover the pattern of the area between all the different triangle shapes.

The video exemplar inspired a group of teachers to plan and implement a lesson for their Grade 4/5 students to find the area of the triangle. For the most part, the teachers in this group were new to Lesson Study. They had not hosted a Math Fair. However, one

member had been part our Lesson Study group for several years. The teachers planned together in their own school and invited us to video record when they began to teach the lesson.

We found that the mathematical nuances of Dr. Takahashi's teaching were missed entirely by our teachers. Dr. Takahashi bound the exploration strongly by the rules and discipline of geometry. He chose exact triangles in a specific sequence all the while enforcing precision accuracy. Each of his students discovered the generality for the area of a triangle. Dr. Takahashi's accompanying Lesson Plan (2002a) provided the goals for what he wanted the students to learn. The Lesson did not spell out the specifics that were demonstrated in the video. The teachers borrowed heavily from the Takahashi's Lesson Plan (Takahashi, 2002a) adding only the outcomes from the Program of Studies for Mathematics (Alberta Education, 1997).

What we witnessed when we came to video was constructivist practice interpreted at its worst. The lesson was very unstructured. In the class prior to our arrival students were instructed to draw and cut out a triangle, any triangle on plain white paper. Without the use of rulers and unbounded by the nature of geometry, students created sloppy, uneven shapes all less than 3 centimetres in height or length. When we arrived the sloppy triangles were pinned to a board at the front of the room. Students were instructed to remove their triangles and using any tools they wanted, find the area of the triangle. Towards the latter part of the class students came together to discuss their findings. The teachers listened, never interrupted, never corrected mistakes and never directed the students understanding into the discipline. Student activity was isolated from the

discipline that would have held activity in place. When most of the class did not arrive at a generalization for the area of the triangle, the teachers were quick to blame the students.

Like their students, the teachers were on their own to try an unfamiliar practice with unclear and poorly understood tools for guidance. In Alberta, teachers are used to both this type of professional learning and also its accompanying failure to provide real instructional improvement. Brought together to discuss and plan new practices, they are left to their own to figure out how to implement the new practices in their own classrooms. It is not yet common practice to provide teachers with professional learning opportunities within the context of their own classrooms. In our previous research we had documented teachers' learning gains when provided with a combination of offsite group learning and situated contextual professional learning. Stretched to volunteer our time for monthly group meetings and amateur video and editing, we have had no choice but to restrict our Lesson Study to providing an opportunity for teachers to learn mathematics and to design lessons for their respective classrooms. Our research has shown that while teachers still continue to learn mathematics and design lessons; without the added support within their classrooms most teachers are not able to transfer their learnings into the context of their own classrooms.

Does A Math Fair Help Teachers Transfer Learning: A Case Study With Fractions

We wanted to know whether a teacher who had hosted a Math Fair would be more successful in trying out new instructional mathematics practices.

When we walked into the classroom, the energy level in the classroom on that first day was electric. Sandy's room was overflowing with books, manipulatives, and students work. Students were grouped around hexagonal tables and their voices were

buzzing. Some were seated; some were walking around talking to students at other tables; some were trying to get Sandy's attention. Sandy appeared completely at ease within this vibrant environment; the students appeared keen and excited as they tackled the problem Egyptian Fractions, which appeared on a SMART Board™² at the front of the classroom.

Egyptian Fractions³

The Egyptians only used fractions with a numerator of 1. Take the fraction 80/100 and keep subtracting the largest possible Egyptian fraction till you get to zero. Three Egyptian fractions are enough:

$$80/100 = 1/2 + 1/4 + 1/20$$

Do the same for 85/100, 90/100, 95/100, and if you are particularly fond of Egyptians, 99/100

As the students started to work on this problem some misconceptions about fractions became increasingly apparent. It was clear that a number of students were trying to recall a procedure that Sandy had previously introduced to them using the first example of 80/100. Similar to Hiebert's (2005) observation of North American classrooms, Sandy had demonstrated a procedure for breaking the larger fraction into smaller fractions. Brian⁴ worked through the problem as shown in Figure 1. He had accurately broken the fraction into two smaller fractions: $85/100 = 75/100 + 10/100$. He worked procedurally to break the smaller fractions into smaller fractions; however, as shown in Figure 1, Brian's over dependency on procedural knowledge soon started to

² An interactive whiteboard.

³ Galileo Educational Network,
<http://www.galileo.org/math/puzzles/EgyptianFractions.html>

⁴ All students' names are pseudonyms

show some significant conceptual misunderstandings. Brian did not write the denominator in the next iteration of breaking the fraction into smaller fractions.

$\frac{75}{100}$ $\square \square$ $25 + 50$ $\downarrow \quad \downarrow$ $\frac{1}{4} + \frac{1}{2}$	$\frac{10}{100}$ $\square \square$ $5 + 5$ $\downarrow \quad \downarrow$ $\frac{1}{2} + \frac{1}{2}$
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Figure 1: Brian's Solution

Krista: "How did you get the two 1/2 fractions?"

Brian: "I just divided the 5 by 10 to get 1/2."

Brian's error provided an excellent opportunity to confront him with what he could not see and did not understand. When Krista asked him if " $1/2 + 1/2$ equalled $10/100$ ", he silently shook his head. "I must have made a mistake". He gazed back at his work. Knowing he was wrong, but not knowing what was wrong, left him unsure of what to do next. He had no further strategies to draw upon.

There are two ways that people attempt to solve problems: (1) *direct translation strategy* and (2) *problem model strategy*. The direct translation strategy for solving a mathematical problem uses a procedure of picking numbers from the problem and performing arithmetic operations on them. This 'short-cut' procedural approach emphasizes calculation. A problem model strategy emphasizes finding the relationships among the variables in the problem. This procedure begins with the person trying to

understand the situation described and establishing a solution based on their representation of the situation (Mayer & Hegarty, 1996).

The *direct translation strategy* is a common method for less successful problem solvers. North American children are more likely to engage in short-cut procedural approaches to solving problems and instruction is more likely to emphasize computing correct numerical answers rather than understanding the problem (Friesen, 2005; Stigler & Hiebert, 1999). Procedural problem solving is the most common in North American classrooms (Hiebert, 2005).

While *direct translation strategy* makes minimal demands on memory and does not require extensive knowledge of problem types, it frequently leads to erroneous answers. Similarly, *direct translation strategy* is not productive for solving non-routine problems (Mayer & Hegarty, 1996). Routine problems are problems that learners know how to solve based on past experience. Non-routine problems are problems that the learner does not immediately know how to solve (Kilpatrick, Swafford, & Findell, 2001).

Brian's error in the example above demonstrates his *direct translation strategy* for solving the problem. Brian was trying to follow the procedure demonstrated by his teacher. As we continued to move about the classroom, we found that most of the students tried to follow Sandy's procedure for solving the problem.

The solution to the Egyptian Fraction problem requires the subtraction of "the largest possible Egyptian fraction till you get to zero." (GENA, 2008b, ¶ Egyptian Fractions) For $85/100$, the second largest fraction is not $1/4$, but $1/3$. None of the students in the class had come upon this realization. All were working with $1/4$ as the second largest fraction. The students realized that $1/4$ was not working but they were unsure

what fraction they might try instead. Krista suggested that they try $\frac{1}{3}$. As the students set about the problem again, many struggled with how to proceed. Sandy's problem solution procedure would not work as easily.

One group of four girls worked with coloured wooden blocks to solve their problem. They engaged in a heated discussion about how to divide the hundred's block into $\frac{1}{3}$. After much consternation and debate, they finally agreed that the hundreds block could not be divided into thirds. Fully convinced they announced that the problem could not be solved. Krista rebutted their claim and assured them that indeed, the problem did have a solution. After all, the Egyptians had figured out how to solve it.

Knowing how to create a common denominator with fractions $\frac{85}{100}$ and $\frac{1}{3}$ eluded the students. It didn't take long before other misconceptions about fractions were illuminated. These students had memorized a set of procedures but had no conceptual understanding of the problem and limited procedural fluency with fractions.

Seeing that the children were struggling with the problem, Sandy would pull children aside to a table at the back of the classroom for assistance. By the end of the Egyptian Fraction class time, Sandy was surprised to see how many of her students were struggling with the concept of fractions. Many teachers would have been quite distraught with this finding, but not Sandy. She saw this problem as an opportunity to learn something about her students. In reflecting on the students' experience, Sandy said, "I've learned an tremendous amount about their understanding of fractions from this problem."

In this investigation, Sandy was working in what Donovan and Bransford (2005) term an effective learning environment. In the *learner-centered lens* students' misconceptions and misunderstandings about fractions became apparent. This enabled

Sandy to know where instruction was needed to move into the *knowledge-centered lens*. Within the *assessment-centered lens*, student thinking and learning became visible. This provided a guide for both Sandy and her students in learning and instruction. The questioning, the dialog, the respect and the risk taking were all indicative of the *community-centered lens*. An incredible space for exploration of fractions had been opened up. However, confronted with the realities of teaching a densely-packed curriculum in an examination year⁵, Sandy faced a dilemma. Should she devote more time to this problem and fractions in general or should she carry on with other content that was also pressing at this time of the year. Sandy made the decision to move on.

“Unfortunately, we don’t have any more time than this class to devote to fractions. It is near the end of the year and we still have so much to cover.”

Fractions and proportional thinking are foundational concepts in mathematics. The Egyptian Fractions Problem helped to expose these Grade 6 students’ superficial understanding and misunderstanding of fractions. This is particularly worrisome as these students will carry their fragile knowledge of fractions into next year’s study of proportions. But fostering deeper understandings takes time and effective instruction; time to play, to ponder, to think, to forward and justify solutions and instruction attuned to the students’ emerging understanding and tethered strongly to the discipline of mathematics.

When Sandy demonstrated an algorithm for her students, typical of the North American teaching script she stripped fractions from their mathematical “community of relations” (S. Friesen et al., 2008, p. 118) into fragments and isolated rote facts and

⁵ All Grade 6 students in Alberta write standardized provincial examinations in Mathematics, Science, Social Studies and Language Arts.

procedures. When the problem strayed from the algorithm, Sandy's students' fragile mathematical knowledge came forward. At the end of the year, Sandy's teaching focus was pressured and influenced by the high stakes provincial exam. She felt pressured to move on to 'cover' the curriculum.

While Sandy was unable to fully transfer her learning from Lesson Study into her practice, her experience with Math Fairs allowed her to make further progress in improving her instructional practices than a teacher who was involved in Lesson Study alone. We should also note, that Sandy was able to reflect on her practice in ways that the teachers involved in Lesson Study alone were not able to do. In time, with continued reflection, Sandy might be able to further improve her instructional practices, more attuned to her students' understanding and tethered more deeply to the discipline of mathematics.

Endbit

Changing and improving mathematics instruction is a multifaceted complex endeavour in North America. While significant money has been expended on teacher learning to improve teachers' understanding and practice of mathematics, in order to improve the quality of student learning, little progress has been made (Mizell, 2007; Sawchuk, 2008; Smith, Desimone, & Ueno, 2005).

Loss of funding has provided us with the opportunity to study the effectiveness of (i) Math Fairs when combined with monthly Lesson Study professional learning opportunities without classroom mentorship and (ii) monthly Lesson Study professional learning without Math Fairs or classroom mentorship. Our research has shown that, in

Alberta, our combination of Math Fairs, Lesson Study and classroom mentorship was very effective in bringing about the changes and improvement to teachers' understanding and practice of mathematics. Math Fair interrupts the everydayness of teaching mathematics and provides teachers with insight into how mathematics might be taught differently. Their students' excitement and intellectual engagement observed in Math Fair encourages teachers to explore a different practice at Lesson Study. After Math Fair at Lesson Study, teachers are willing to explore mathematics and develop lessons that lead to rich mathematical inquiries. Mentorship in classrooms with Galileo's mathematics educators helps teachers shape the lessons into effective changes in practice. We acknowledge that the changes to teaching practice are not instantaneous. However, we have seen how a combination of Math Fair, Lesson Study and classroom mentorship lead to a profound progression into teaching mathematics in connected relational nature.

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What teachers' want: Identifying mathematics teachers' professional learning needs

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Abstract: *This paper reports on three differing approaches to ascertaining the professional learning (PL) needs of teachers of mathematics that were used in three PL projects. In each case the approach used was constrained to some extent by the project brief, practical considerations, and stakeholders' preferences and abilities to contribute to determining the most useful focus of the PL. Nevertheless, there were consistent efforts to heed the advice in the literature about effective PL focussing on teachers' needs in their particular contexts. The results of each approach are described and lessons about effective ways to identify mathematics teachers' PL needs, and reasons for which teachers might be unwilling or unable to articulate their needs, are drawn from an overall analysis of the findings in relation to relevant literature on effective PL and teacher belief change.*

Keywords: Professional learning; teacher beliefs; teacher change; Mathematics teacher professional development

Reports of Professional Learning (PL) initiatives tend to focus on the process and outcomes of the PL often describing how the generally accepted characteristics of effective learning were incorporated in the PL design (e.g., Beswick & Jones, 2011; Muir, Beswick & Williamson, 2010; Watson, Beswick & Brown, 2012). There appears to be relatively little attention to ways in which PL providers find out about teachers' perceived needs and particularly the extent to which these efforts were either effective in eliciting teachers' needs, or in driving PL. This paper examines the efforts made to identify teachers' PL needs and the resulting information obtained in three projects. It suggests circumstances that, when in place, may increase the value of seeking teacher input about their needs and raises questions about the purpose and value of seeking such information in circumstances that are likely to render it ineffective or inappropriate. The role of contextual factors including policy and curricula changes in influencing teachers' PL needs or PL programs is seldom mentioned in the

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literature perhaps because such things are beyond the scope of PL providers to address. A further contribution of this paper is the illustration it provides of the impacts of such factors on teachers' PL needs.

Teachers' needs as foci of professional learning

Common to many lists of features of effective PL is the need for it to address teachers' needs (Sowder, 2007). Different lists place differing emphasis on the importance of involving teachers in the identification of those needs. Elmore (2002), for example, described appropriate PL foci as issues identified from research or considered to be best practice whereas Clarke (1994) proposed that the issues addressed should be in large part identified by the participating teachers. The strongest emphasis on basing PL on teachers' self-identified needs was provided by Hawley and Valli (1999) who claimed teachers should not only be involved in the identification of their needs but also involved where possible in designing the ways in which they might be addressed. Even if the importance of involving teachers in identifying their needs is accepted there are difficulties associated with PL providers finding out directly from teachers what they are.

In addition to the fact that much teacher knowledge is tacit (Eraut, 2000) and hence not available to be shared, there are reasons for which teachers may choose not to share information about their PL needs. Firstly, revealing needs makes one vulnerable and in a professional context is accompanied by the risk of appearing other than competent. This is evident in groups set up to provide opportunities for teachers to discuss their work (Wilson & Berne, 1999) but applies also when teachers are asked to write about their needs knowing that PL providers will read their comments. Secondly, Wilson and Berne (1999) speculated that a climate of anti-intellectualism that they believed had influenced American schooling at the time may have affected teachers' responses to PL. In contexts in which policy settings appear politically driven rather than based upon considerations of evidence, teachers may be reluctant to engage intellectually. Indeed, teachers may justifiably be sceptical about how and to what extent the needs they articulate will actually be factored into ensuing PL. A third and related factor could be teachers' perceptions of the status of their profession. The status of the teaching profession is of concern in many countries (e.g., Australian Council for Educational Research, 2013; Bland et al., 2011; European Commission, 2012; Hargreaves et al., 2006). Teachers who feel under-appreciated may be unlikely to believe that proposed PL will in fact respect or respond to their input. Fourthly, Wilson and Berne (1999, p. 186) pointed to the

“privacy of teaching” as contributing negatively to “the development of critical dialogue about practice and ideas”.

Even if teachers articulate clear ideas about what they see as important issues for PL to address, these may well change over time, perhaps even between the planning and the implementation of the PL (Sowder, 2007). The need for ongoing dialogue in an environment of mutual trust appears necessary not just to facilitate participants’ learning (Borko, 2004) but also to refine and adapt the focus of PL in as ongoing process (Wilson & Berne, 1999).

Learning as beliefs change

Considering teacher learning from the perspective of beliefs change can offer some useful insights into the issues raised in the previous section as well as highlighting some additional points relevant to the identification of teachers’ PL needs.

Sowder (2007), in her review of literature on the mathematical education and development of teachers included among the goals for that development, the growth of a “sense of self as a teacher of mathematics” (p. 167). PL is inextricably linked to beliefs about oneself or one’s identity as a competent teacher. Beliefs about oneself are among the most centrally held (Cooney, Shealy & Arvold, 1998) in the sense of being strongly and extensively interlinked with other beliefs in the one’s belief system (Green, 1971). Beliefs connected to those about self as a competent teacher of mathematics are likely to include beliefs about what it means to teach and to learn mathematics, how and under what conditions mathematics teaching and learning occur most effectively, the teachers’ role, and students’ capacities to learn mathematics (Beswick, 2007). Beliefs in relation to any of these things could be objects for change from the perspective of a PL program. The greater the extent of their connection to teachers’ beliefs about themselves the greater the likelihood that change to them will be experienced as personally confronting, emotional, and difficult, and hence resisted. It is unsurprising that stories of profound teacher belief and practice change are often represented in terms of personal transformation as the result of a long and sometimes difficult journey (e.g., Chapman & Heater, 2010).

Wilson and Cooney (2002, p. 134) claimed that “teachers’ beliefs can change when they are provided opportunities to consider and challenge those beliefs”. Given that the provision of such opportunities is an important role of PL, its effectiveness would seem to be dependent upon it addressing relevant beliefs. A necessary pre-requisite would be that PL providers are aware of the relevant beliefs that teachers bring. Logically, teachers have at least three

categories of beliefs about their PL needs. These are: (1) beliefs of which they are aware and are happy to share. These are likely to relate to things without close connection to their identity as a competent mathematics teacher such as needs for more time, or concrete resources – all things that can be addressed without personal challenge; (2) beliefs of which they are aware but are unwilling to share (for reasons including those outlined in the previous section); (3) beliefs of which they are not aware. Getting teachers to reveal beliefs in the second category requires addressing issues of trust (Wilson & Berne, 1999) that may include wider cultural and societal issues such as the status of teachers and teaching. The third category cannot, by definition, be uncovered by asking teachers directly about their needs. It may be possible, however, to bring beliefs in this category to teachers' consciousness by providing appropriate prompts to which they can respond. This may happen at the start of a PL program. Alternatively and/or in addition, revealing these beliefs with a view to addressing them, can be seen as part of the role of PL.

THREE PROFESSIONAL LEARNING PROJECTS

An overview of relevant contextual information is provided before each of the three projects is discussed in turn.

Context of the projects

The three projects were conducted in the Australian island state of Tasmania. Tasmania with an area that is about half that of England occupies just 1% of Australia's land area (Geoscience Australia, 2009) with mountainous terrain in parts and a geographically dispersed population of approximately 0.5 million (Tasmanian Department of Treasury and Finance, 2012). In addition, Tasmania is Australia's most economically disadvantaged state. More than one third of the population is dependent upon government financial assistance (ABS, 2007), and only 55% of students complete Year 12, compared to a national average of 62% (ABS, 2008).

In Australia, as in many European countries, numeracy is used to refer not only to the use basic, largely computational skills in everyday contexts but also to the application of a much wider range of mathematical skills. It is thus akin to Steen's (2001) notion of quantitative literacy or De Lange's (2003) mathematical literacy. In most Australian states, including Tasmania the first year of secondary school is Year 7.

The period over which three projects upon which this paper is based were conducted (2004-2007) was a time of considerable curriculum upheaval in Tasmania. Early in the period an

innovative values-based curriculum framework was established with an emphasis on pedagogy and cross-curricula learning (Department of Education, Tasmanian [DoET], 2002, 2003). The Essential Learnings (ELs) frameworks 1 and 2 identified 18 Key elements within five ELs (Thinking, Communicating, Social Responsibility, World Futures and Personal Futures). Traditional learning areas such as mathematics were not specifically addressed but “Being Numerate” was a key element in the Communicating Essential against which teachers were required to report from 2005. Despite extensive consultation throughout its development and considerable investment in PL for teachers, the ELs curriculum encountered controversy as it was implemented. This culminated in 2007 with the introduction of a new Tasmanian curriculum (DoET, 2007). Although announced as a refinement of the ELs, the new curriculum framework identified eight curriculum areas that aligned with traditional school subjects and included Mathematics/Numeracy. Further detail of the circumstances surrounding the demise of the ELs is provided by Watson, Beswick and Brown (2012).

Being Numerate in the Middle Years (BNMY)

BNMY was a 6-day PL program aimed at improving numeracy outcomes of middle years (Years 5-8) students that ran over a single year in each of 2004, 2005 and 2006. In the first iteration the 6 days were fitted into the period August to November (the end of the school year) but in subsequent iterations they were able to be spread across the school year in three pairs of consecutive days. In each case between 37 and 52 teachers, made up of 3-5 from each school participated. The first 2 years involved secondary schools and their feeder primary schools, whereas in the third year participants were drawn from K-10 district schools. Most of the secondary teacher participants across the three years reported having taken mathematics courses as part of their university teaching degrees and some had completed bachelor degrees in Science with components of mathematics prior to their teaching qualification. The primary teachers reported having studied mathematics curriculum units as parts of the pre-service teaching qualifications. The program was delivered by members of the state and district numeracy teams and university mathematics education researchers. Details of the program and its outcomes were reported by Watson, Beswick, Caney and Skalicky (2006) and Watson and Beswick (2011).

Identifying the needs of the BNMY teachers

The content of the first iteration of the program was determined on the basis of the experience of the DoET numeracy support team, research on the development of student and teacher

understanding, and input from a teacher representative from each of the participating schools. Throughout the program, including its second and third iterations, adjustments were made on the basis of presenters' observations, teacher feedback collected at the ends of each session, teacher profiles completed on the first and last days of each iteration.

Teacher profile. The teacher profile, adapted from that of Watson (2001), included sections designed to assess an holistic conceptualisation of teacher knowledge that included teacher beliefs and confidence as well as the seven aspects of teacher knowledge identified by Shulman (1987). In the context of mathematics teaching the seven knowledge types were; (a) mathematical content knowledge, (b) general pedagogical knowledge; (c) mathematics curriculum knowledge; (d) mathematical pedagogical content knowledge; (e) knowledge of mathematics learners; (f) knowledge of education contexts; and (g) knowledge of the ends, purposes, and values of education related to mathematics. Teachers were asked about their confidence to develop students' understanding of each of fractions, decimals, percent, ratio and proportion, numeracy across the curriculum, critical numeracy in the media, mental computation (addition and subtraction of whole numbers), mental computation (multiplication and division of whole numbers), and operations with fractions. In addition, teachers were asked about their PL needs in relation to each of; their personal understanding of mathematics, resources, using technology, understanding students as learners, assessment of understanding, and teaching for understanding. Although data from all sections of the profile provided insight into the content and nature of PL that might be beneficial, the sections asking about their confidence in relation to teaching various aspects of middle school mathematics and their PL needs are of most direct relevance.

PL needs of BNMY teachers

The DoET numeracy support team and school representatives were concerned about the teachers' ability to teach mental computation related to learning tables, and fractions, decimals, and percentages. Secondary teachers were, unsurprisingly more confident on average than their primary colleagues. All teachers were most confident about their ability to teach mental computation involving the addition and subtraction of whole numbers. Aspects in relation to which both primary and secondary teachers tended to be least confident were *ratio and proportion* and *critical numeracy in the media*. Teachers reported relatively little confidence in relation to *connecting numeracy across the curriculum*, and operations with both fractions and decimals.

Teachers' responses to the profile section asking them to nominate their PL needs are shown in Table 1 in relation to each of the six categories that they were prompted to consider. The figures are percentages of the total number of teachers who completed the profile. The 'no response' category includes those who left the space blank or provided a response that was uninterpretable. 'Required without comment' indicates a brief response indicating a need but providing no elaboration (e.g., "yes", "a major need"). The total percentages of teachers who expressed a need for PL with or without comment are shown in the italicised row. For each category from one fifth to almost one half of teachers did not provide a response and many of the teachers who indicated that PL was required in a particular area provided no further elaboration. The areas in which teachers most commonly expressed a need for PL were in relation to *resources*, their *personal understanding of mathematics*, and *assessment of understanding*.

Table 1

Overview of teachers' self-assessed PL needs at the start of the first BNMY program ($n=48$)

	Personal understanding of mathematics	Resources	Using technology	Understanding students as learners	Assessment of understanding	Teaching for understanding
No response	22.9	22.9	33.3	43.8	27.1	47.9
Required without comment	35.4	6.3	27.1	16.7	37.5	27.1
Required with comment	37.5	66.7	33.3	31.3	35.4	25.0
<i>Total required</i>	<i>72.9</i>	<i>73.0</i>	<i>60.4</i>	<i>48.0</i>	<i>72.9</i>	<i>52.1</i>
Not required	4.2	4.2	6.3	8.38	0.0	0.0

Of those teachers who indicated a need and provided some further comment, most addressed the area of *personal understanding of mathematics* in relation to their teaching. Nevertheless, comments related to the ELs curriculum rather than to aspects of mathematical content. For example, one wrote, "My understanding of how mathematics and numeracy fits in with the ELs Framework needs to improve". Several teachers identified specific content areas, such as decimals and fractions, in terms of communicating ideas to students.

Overall, *resources* was the category in relation to which teachers made the most comments with new materials and time two issues that many teachers raised. The comments regarding material resources included needing “multiple copies,” and “concrete aids.” Several teachers alluded to a need for resources regarding the sequencing of ideas, Comments about time included being able to plan “individually and collectively” and needing time “to make and discuss use of [resources] with other teachers.” Issues of access and availability arose in the area of *using technology*, which are perhaps not as relevant in terms of professional learning; however, several individual teachers indicated that PL would helpful in relation to the more effective use of ICT in planning and to enhance students’ learning would be useful.

Few teachers made specific comments on *teaching for understanding* but several teachers emphasised the need to link concepts to everyday life. Most of the comments regarding *assessment of understanding* focused on assessing numeracy within the ELs framework. Two teachers mentioned that moving beyond testing and tasks that did not involve “a pen and paper test or computer test” was an area of need for them.

Issues regarding student engagement and catering for students’ diverse needs arose for some teachers in assessing their needs in relation to *understanding students as learners*. One teacher commented, “Would like to gain better understanding about the different ways children may think - different strategies to offer them.”

Providing the Mathematical Foundation for an Innovative Australia within Reform-Based Learning Environments (MARBLE)

MARBLE was a 3-year project (2005-2007) conceived in the context of the newly developed ELs curriculum and operating through the time in which ELs were replaced with a new Tasmania curriculum. It was founded on a view of PL as development of knowledge holistically defined to include Shulman’s knowledge types applied to mathematics, teacher confidence and beliefs (Beswick, Callingham & Watson, 2012). PL was provided by university mathematics education researchers, and relevant personnel from the DoET and Catholic Education Office (CEO). The major aims of the project were:

1. To investigate the effectiveness of school-based, negotiated PL for teachers of mathematics that is consistent with recommendations of research in the field and evaluated in terms of evidence-based student and teacher outcomes.
2. To develop a model and make recommendations for effective teacher professional learning that meets the requirements of both reform and innovation.

The project involved all middle school teachers in nine schools, forming two clusters – one in the south of the state and one in the north. One of the northern schools, one was part of the Catholic school system while the others were government schools. The government schools comprised four district schools (K-10), 3 primary schools, and one secondary school (7-10). The Catholic school catered for students in Years K-10. Because of transfers among schools and some overlap of schools involved, some of the teachers in MARBLE had been participants in BNMY (Watson et al., 2012).

As described by Watson et al. (2012), although the same schools were involved across the 3 years of the project, the numbers of teachers varied from 42 at the start of the first year to 54 at the start of the final year. This represented a total of 86 teachers who were involved in the project for some part of the time. Of these, just 19 participated for the full 3 years. High teacher attrition was largely a consequence of high rates of transfer out of the schools, most of which were considered difficult to staff. Eight of the teachers who participated in the first year and none in subsequent years claimed to have studied enough mathematics to amount to a major in the discipline (Watson et al., 2012). Aspects of the project and its outcomes have been reported in Beswick et al. (2012), Beswick, Watson and Brown (2006), Watson, Beswick and Brown (2006), and Watson, Beswick, Brown and Callingham (2007).

Identifying the needs of the MARBLE teachers

As in BNMY, a teacher from each participating school met with the researchers, DoET and CEO personnel prior to the start of the project to discuss the PL needs of middle school teachers in their schools and all teachers commencing the program were asked to complete a teacher profile that included sections on their confidence to teach aspects of mathematics. In addition, teachers in the southern cluster provided feedback on an initial PL day that was conducted prior to the start of the project, exit surveys that included questions about PL needs were administered to teachers leaving the project before its conclusion, and teacher input was sought throughout the 3 years in meetings of the school representatives, researchers, and DoET and CEO personnel, as well as informally in the context of PL sessions where all participants were present.

Teacher profile. An initial teacher profile, similar to that used in BNMY, was administered at the start of the project and where possible to new teachers at the start of subsequent years. The final profile was administered at the end of the 3 years and to teachers leaving the project at any time whenever this was feasible. Despite efforts to capture all beginning and finishing

teachers, just 25 teachers completed both profiles. The most relevant sections to ascertaining teachers' PL needs asked teachers to rate on 5-point Likert scales their confidence in relation to a range of aspects of mathematics teaching and asked teachers to identify their PL needs in relation to each of seven aspects. The confidence items related to; fractions, decimals, percent, ratio and proportion, Measurement, Space, Pattern and Algebra, Chance and Data, mental computation, connecting mathematics to other key learning areas, critical numeracy in the media, and assessment of 'Being Numerate' against the ELs standards. Teachers were asked to indicate their PL needs in relation to each of; your personal understanding of mathematics, resources and concrete materials, using technology and the media, understanding students as learners, assessment of understanding, teaching for understanding, and linking your mathematics teaching to the other ELs key elements.

PL needs of MARBLE teachers

The concerns of DoET and CEO personnel and school representatives were broadly the same as for BNMY in that they recommended a focus on mental computation and fractions, decimals and percent. As reported by Beswick et al. (2006) in relation to the strands of the mathematics curriculum, the teachers expressed most confidence about teaching *Measurement* and *Space*, and least confidence in relation to *Pattern and Algebra*. Approximately one third of teachers also indicated a lack of confidence in relation to each of *fractions*, *decimals*, and *percent*. Teachers were particularly lacking in confidence in relation to *ratio and proportion*. Fractions, decimals and percent are, of course, connected to proportional reasoning and constitute arguably the most crucial elements of middle school mathematics (Sowder, Armstrong, Lamon, Simon, Sowder, & Thompson, 1998). Approximately one third of the teachers expressed a lack of confidence in their ability to make connections between mathematics and the Key Elements of the ELs and to assess the Being numerate key element against the ELs standards.

Table 2 shows the results of a similar categorisation to that used for the BNMY responses, of teachers expressed PL needs in relation to each of the eight aspects on which they were asked to comment. The figures are percentages of the total number of teachers who completed the profile. From close to one third to approaching two thirds of teachers provided no meaningful response. The areas in which teachers most commonly expressed a need for PL were in relation to *teaching for understanding*, *using technology and the media*, and *resources and concrete materials*.

In relation to *personal understanding of mathematics*, few responses identified specific topics. There were single mentions of the curriculum strands Chance and Data, and Space as well as problem solving, decimals, ratio and percent. Many comments related to pedagogy, for example, “Better ways to teach topics. Knowing what we do not need to teach in primary school. How we can get parents, who wish to, to help students” and “Reminders of how children develop mathematical concepts. How to reach those kids who "just don't get it”.

Comments on resources focused on the need for more concrete materials and the need for time to become familiar with their use and to incorporate them into planning. Some teachers expressed a need to for greater awareness of what is available. Technology related needs included a desire for more computers; improved access to computers; more ideas, activities, software and recommended websites; and more time for planning. Several responses reflected a desire to better use technology to support students’ learning. Individual teachers expressed a need for learning about particular software packages and applications such as spread sheets, as well as graphics calculators.

The very high non-response rate in relation to using the media appears to reflect a lack of familiarity with using it as a teaching resource. The few comments provided support this. They included “Haven't really used this as a resource”, and “have not used the media in relation to numeracy”.

Table 2

Overview of teachers' self-assessed PL needs at the start of the MARBLE program ($n=42$)

	Personal understanding of mathematics (%+ Resources and concrete materials	Using technology	Using the media	Understanding students as learners	Assessment of understanding	Teaching for understanding	Linking your mathematics teaching to the other ELs key elements	
No response	45.2	38.1	35.7	61.9	54.8	50.0	28.6	54.8
Required without comment	14.3	16.7	21.4	16.7	16.7	14.3	23.8	31.0
Required with comment	33.3	35.7	33.3	11.9	16.7	26.9	42.9	4.7
<i>Total required</i>	<i>47.6</i>	<i>52.4</i>	<i>54.7</i>	<i>28.6</i>	<i>33.4</i>	<i>41.0</i>	<i>66.7</i>	<i>35.7</i>
Not required	7.1	9.5	9.5	9.5	11.9	9.5	4.8	9.5

Comments made in relation to *understanding students as learners* were quite generic and included “Have learnt a lot through observation and reading”, “I don't really, with regard to numeracy”, and “Could know more, probably”. One expressed an interest in learning about differences in male and female thinking.

In relation to *assessment of understanding* many teachers related their comments to the ELs frameworks. Many also mentioned approaches to assessment that the DoET was advocating in connections with the ELs curriculum. These included the design and use of rubrics for assessment, designing tasks and ways of assessing without using tests.

Teachers' comments about their needs in relation to teaching for understanding included a desire for PL that was mathematics specific and that included practical examples (in contrast to the extensive PL that had been provided about this aspect in a generic sense as part of the implementation of the ELs), to find out about primary teachers teach. Teachers' responses included, "How do I know they really understand?" and they were concerned to learn strategies that would assist students to "retain knowledge and skills".

Comments on linking mathematics with the ELs were few. Those offered were positive about working collaboratively (as encouraged by the DoET as the ELs were being implemented) or expressed a desire for more sharing.

Building Mathematics Teaching and Leadership Capacity (BMTLC)

The BMTLC project ran in 2007 and offered an intensive week of PL to teachers in three geographically isolated schools. The project was sponsored by the Australian Association of Mathematics Teachers (AAMT) and its aims were:

1. To provide support for teachers of mathematics in a cluster of remote Tasmanian schools.
2. To develop mathematics curriculum leadership in the area.
3. To raise the profile and impact of the Mathematical Association of Tasmania (MAT), an affiliate of the Australian Association of Mathematics Teachers (AAMT), in the area.

The model, described in detail by Beswick and Jones (2011), involved sending a team of five PL providers made up of university academics and DoET personnel to the school cluster for 1-3 days each over the course of the same week to provide a total of 10 person-days of PL. It was designed to respond to the specific needs of teachers in their teaching context and to avoid the difficulties inherent in having to travel to a larger centre for PL. Two of the schools catered for students in Years K-12 and had enrolments of 610 and 380 students while the third, a K-6 school, had an enrolment of 70 students.

A total of 43 teachers of mathematics from K-12 participated in at least one part of the PL program. No more than three teachers had any university mathematics as part of their qualifications. Of these, one, who taught Year 11 and Year 12 mathematics across the two schools that catered for these year levels, had a major in mathematics. The remaining two taught Year 9 and Year 10 mathematics. Enrolments in the senior secondary years were small

with many students opting to relocate to a larger centre to study in schools with the capacity to provide a broader range of courses at this level.

Identifying the needs of the BMTLC teachers

The project organiser who was not one of the PL providers visited the schools for 2 days prior to the PL week to administer a survey, conduct informal interviews with the principals and teachers (individually and in groups), and to negotiate the details of arrangements for the PL week. A 15 page summary of the data gathered in this exercise was provided to the PL providers several weeks before they visited the schools. The schools were provided with brief biographies of the PL providers along with ways in which they were happy to work with teachers (e.g., working with individual or small groups of teachers, conducting demonstration lessons, working alongside teachers in their classrooms, running after-school workshops) and a timetable indicating which PL providers would be in the area on which days and in which schools they would be based for particular days (the PL providers' time was divided amongst the schools in proportion to their enrolments). Schools were asked to add to the timetable the names of teachers who would work with each PL provider at each time and the kinds of activities and topics that they wanted.

The teacher survey. The survey included an AAMT survey designed to help teachers to reflect on their own work in relation to the Standards for Excellence in Teaching Mathematics (AAMT, 2002; 2006). These sections asked teachers to respond on three 4-point Likert type scales to items that addressed: their professional knowledge of students, of mathematics, and of students' learning; and their professional practice. The three scales for each item related to, (1) the importance of the item in their context, (2) their self-rating of their own knowledge, and (3) the priority of each aspect for improvement/PL. Additional items were similar to those used in teacher profiles in both BNMY and MARBLE. They included items asking teachers to rate their confidence to teach; whole number place value, addition and subtraction of whole numbers, multiplication and division of whole numbers, fractions, decimals, percent, ration and proportion, Measurement, Space, Pattern and basic Algebra (K-8), algebra (beyond Year 8), Chance and Data, mental computation, and connecting mathematics to other key learning areas. Open response items prompted teachers to nominate topics that were difficult to teach, and to indicate their PL needs in relation to; their personal understanding of mathematics, resources and concrete materials for

mathematics teaching, using technology and the media in mathematics teaching, understanding students as learners of mathematics, assessment of students' understanding of mathematics, and teaching mathematics for understanding.

PL needs of BMTLC teachers

Conversations with teachers and principals were consistent with the results of the survey and although far less detailed. The survey results that relate directly to PL needs are summarised below.

Teachers' confidence was greatest in relation to teaching operations with whole numbers, particularly addition and subtraction, measurement, whole number place value and mental computation. Teachers were least confident about *Algebra (beyond Year 8)*, *ratio and proportion*, *connecting maths to other key learning areas*, *Chance and Data*, *percent*, *Pattern and basic Algebra (K-8)*, *decimals*, and *fractions*. Time and money were nominated by early childhood teachers as difficult to teach and ICT and problem solving by teachers of middle and upper grades.

Teachers' priorities for PL with respect to their knowledge of students were in relation to their students' feelings and confidence about learning maths. In relation to knowledge of mathematics, priorities for PL related to knowledge of *connections within mathematics* and *between mathematics and other subjects*, and the mathematics content that they teach. The latter was ranked most important and also most highly in terms of existing knowledge in spite of it being a PL priority. Despite being prioritised for PL, connections between maths and other subject areas was not ranked highly in terms of its importance. In relation to knowledge of students as mathematics learners teachers' considered knowing "a range of effective techniques and strategies for promoting enjoyment of learning and positive attitudes to maths" and "a range of effective strategies and techniques for teaching and learning maths and learning sequences in maths" to be important and also top priorities for PL.

In relation to the learning environments they created, teachers regarded the creation of a safe inclusive environment where engagement with mathematics was valued, students were empowered to be independent learners, individual needs were met, and students were motivated to enjoy and be interested in maths as most important and also as among the highest priorities for PL. Motivating students to improve their maths understandings was rated less important but was among the most highly prioritised items for PL. Of the PL

priorities, teachers rated themselves relatively low in relation to their ability to motivate students both to understand maths and to enjoy and be interested in it.

In relation to their planning for teaching, teachers prioritised using a variety of appropriate teaching strategies, accounting for their students' backgrounds and prior maths learning, using available technologies, providing opportunities for students to explore and apply maths across key learning areas, and building on and enriching students' existing knowledge and appreciation of maths. Of these using technologies was considered less important and teachers, on average ranked themselves lowest in relation to this aspect of their practice.

In terms of their teaching, teachers prioritised providing challenging, engaging lessons that stimulated students' curiosity and supported creativity and risk-taking in finding and explaining solutions. These were among aspects considered most important along with modelling mathematical thinking and reasoning. On average, teachers rated themselves lower for "promote, expect and support creative thinking and mathematical risk-taking in finding and explaining solutions" than for any other aspect.

Teachers indicated that they regarded the most important role of assessment to be providing purposeful feedback to students. They rated themselves highly in terms of feedback to both students and parents and indicated that providing feedback was not a priority for PL. Rather teachers prioritised PL on using records to plan for future learning, maintaining records and using fair, defensible and inclusive assessment strategies.

Table 3 shows teachers responses to the open items asking about their PL needs in six categories analysed in the same way as similar items in BNMY and MARBLE. The figures are percentages of the total number of teachers who completed the survey. The areas in which teachers most commonly expressed a need for PL were in relation to resources, using technology and the media, and personal understanding of mathematics.

Table 3

Overview of teachers' self-assessed PL needs at the start of the BMTLC program ($n=42$)

	Personal understanding of mathematics	Resources and concrete materials for mathematics teaching	Using technology and the media in mathematics teaching	Understanding students as learners of mathematics	Assessment of students' understanding of mathematics	Teaching mathematics for understanding
No response	34.2	34.2	34.2	52.6	44.7	47.4
Required without comment	2.6	5.3	21.1	15.8	26.3	26.3
Required with comment	55.3	60.5	39.5	18.4	26.3	23.7
<i>Total required</i>	<i>57.9</i>	<i>65.8</i>	<i>60.6</i>	<i>34.2</i>	<i>52.6</i>	<i>50.0</i>
Not required	7.9	0.0	5.3	7.9	2.6	2.6

Teachers' comments about their needs in terms of *personal understanding of mathematics* concerned mainly generic issues rather than specific mathematical content. Individual teachers mentioned, for example, needs in relation to catering for diversity, learning sequences, teaching, and helping high and low attainers. The six mentions of specific mathematics topics or curriculum strands all came from teachers of Years 3-6. These were decimals, and chance and data (both mentioned by two teachers), and percent, and algebra for primary students which were mentioned once each.

In relation to *resources and concrete materials for mathematics teaching* teachers expressed needs for specific concrete materials such as counters, games, software, calculators and "good" texts. Rich tasks were mentioned by one K-2 teacher and another teacher of Years 9-12. The majority of responses were, however, non-specific and included "What good

resources are out there?”, “resources to engage low ability students”, and “related to each focus area”. One Year 9-12 teacher mentioned resources for teaching a particular Year 11/12 mathematics course.

Needs related to *using technology and media in mathematics teaching* included, “good” TV recordings, maths programs and CD ROMS, calculator activities, software, games and engaging tasks. Several teachers simply said they needed more. Teachers of younger students were more likely to provide comments in relation to technology and media than were teachers of older students.

Understanding students as learners of mathematics was the area in relation to which teachers were most likely either not to respond or to indicate that PL was not required. Aspects that were mentioned as PL needs included learning styles, individual needs, assessment strategies, and understanding how kids think.

In terms of *assessing students’ understanding of mathematics* teachers indicated that PL about different, alternate and authentic assessment, open-ended tasks, and assessment that is “quick and informative” would be useful, as would time to work with others teaching the same year level. Similar comments were made in relation to *teaching mathematics for understanding*. Teachers mentioned ways of grouping students, “what to do with reluctant learners”, “good assessment tasks”, “brain research”, and “helping under-achievers”.

Summary of perceived PL needs

There were commonalities in the PL needs the teachers indicated in relation to the slightly varied categories that they were prompted to consider in surveys at the start of each of the projects. Resources were among the three most commonly indicated areas of PL need in all three projects, technology or technology and the media was included in this list for two of the three project (MARBLE and BMTLC), as was personal understanding of mathematics (BNMY and BMTLC). Assessment of understanding was among the top three for BNMY and the related teaching for understanding was amongst this list for MARBLE.

In terms of confidence, teachers across all projects reported little confidence in relation to teaching ratio and proportion. Related topics such as decimals, fractions and percent were also commonly at the lower end of the confidence scale. Making connections either across between mathematics/numeracy and other curriculum areas (BNMY and BMTLC) or other elements of the ELs (MARBLE) was a further area of relatively low confidence. Teachers in both BMTLC and MARBLE expressed relatively low confidence in relation to algebra. For

BMTLC, possibly because it involved teachers of Years K-12 rather than only Years 5-8, additional aspects in relation to which confidence tended to be low were algebra beyond Year 8, chance and data, and making connections among topics within mathematics.

DISCUSSION

The three projects had in common participants among whom tertiary level mathematics study was rare, who were located in schools that were either difficult to staff and/or located in rural or isolated areas. In each case initial information about the PL needs of the teachers was sought from informed people such as school teacher representatives, principals, DoET and/or CEO personnel involved in the provision of numeracy support, and from the relevant research literature. Each project used a version of written questionnaire that included confidence items, and several categories in relation to which teachers were asked to indicate what they perceived to be their PL needs.

The projects differed in terms of the amount and structure of PL that was provided, varying from a one week intensive program (BMTLC), through to 6 spaced days over a single year (BNMY) through to a 3-year project (MARBLE). The prevailing agenda of the DoE in relation to curriculum and pedagogy, and the priorities of funding organisations – variously the DoET, CEO, and AAMT also differed and largely explain differences in the projects' objectives. All aimed to improve teaching of mathematics/numeracy but MARBLE began with a particular ELs focus with attendant attention to teaching for understanding, working in cross-curricula ways and using authentic assessment, whereas BMTLC had additional aims in relation to raising awareness of AAMT and its local affiliate, and building teacher capacity through, among other things providing them with a tool that they could use to assess their own teaching, and the relative importance and priority for them of a range of aspects thereof.

Particular curriculum regimes in place at the time were influential in relation to teachers' perceptions of their PL needs. The three iterations of the BNMY project all occurred when the ELs curriculum was being implemented and included the year, (2005) in which Being Numerate was first assessed and reported upon. The BMTLC project in 2007 happened post-ELs as teachers were coming to grips with the new Tasmanian curriculum. The period 2005-2007 during which MARBLE ran spanned the period from when the ELs were most fully implemented and Being Numerate was assessed, through the political controversy that lead to

its axing, and the announcement, creation and implementation of a new curriculum. PL needs expressed in relation to assessment of understanding and teaching for understanding align with the contemporaneous curriculum developments, with 2004 BNMY teachers preparing to assess the Being Numerate element of the ELs for the first time, and the MARBLE teachers feeling perhaps a little more at ease in relation to assessment but aware of their pedagogical needs in terms of teaching for understanding.

PL related to resources and their uses was consistently most requested. Such requests are legitimate (Wilson & Berne, 1999) but are also less potentially threatening to teachers than other aspects such as personal understanding of mathematics because they relate to things that are external to teachers and that are likely to be relatively easily without challenging their views of themselves as competent teachers. This might explain its prevalence amongst teachers' responses. Although personal mathematics understanding was a commonly perceived need by teachers in two of the projects, references to specific topics were scant and often framed in terms of knowledge of how to help students to understand. This was the case even though the questionnaires included lists of topics in relation to which teachers indicated their confidence.

The three projects illustrate the difficulty of obtaining clear, specific and unambiguous information about teachers' PL needs. It could be argued that the kinds of things that teachers expressed could readily have been predicted from the initial conversations with informed people and the research literature, and inferred from the most pressing change agendas impacting or about to impact their work. The few specific topics that were suggested in relation to teachers' personal understanding of mathematics could, for example, have been predicted on the basis of the literature (e.g., Sowder et al., 1998). If this is the case then taking teachers' time to complete questionnaires would appear wasteful if not unethical. In contrast affording teachers an opportunity to express their needs seems appropriate if accompanied by a commitment and the means to address the issues raised.

The BMTLC teacher survey generated considerable additional detail in relation to these teachers' PL needs which was both helpful and unhelpful in relation to PL providers being able to meet these teachers' needs. The 15 page summary that was provided to them was comprehensive and detailed, and required considerable effort for the providers to process. Even with this information, the PL providers found it difficult to know what materials to take with them and how to prepare for their work with the teachers. Several BMLTC PL providers observed that the teachers appeared to be waiting for them to set the agenda and take the lead

in their work together even though they knew that the PL providers were there to help in whatever way the teachers wanted. The providers reported often responding to teachers' on the spot requests and questions rather than using things they had prepared. In spite of this the school principals were all convinced that the teachers' needs had been met (Beswick & Jones, 2011). In this project the questionnaire also served as a means of teachers their awareness of the AAMT standards, and for helping teachers to reflect on their practice, hopefully with a view to working on key aspects of their choosing over the long term rather than simply nominating things in relation to which they wanted specific PL.

These observations highlight three points likely to have been at play in this case and in the other two projects. Firstly, when the teachers in each of the projects filled out the survey many of their PL needs were in the categories of beliefs of which they were aware but unwilling to share, and beliefs of which they were not aware. Articulating needs essentially "in a vacuum" does not assist teachers to become aware of PL needs that don't spring immediately to mind - hence the brevity and frequent non-responses to the open items about PL needs. Providing prompts such as lists of topics in relation to which teachers rated their confidence, or in the case of the BMTLC project, lists of aspects of their knowledge and practice enabled them to nominate as PL needs things that would not have occurred to them when presented with a broad category and blank space. The act of asking teachers to consider such things, thus, influences the teacher's knowledge/beliefs system and may in fact be part of the PL: the awareness raising aspect of the AAMT survey items in the BMTLC project fall into this category. The second point relates to teachers' need to protect beliefs about themselves, including as competent teachers. This has already been alluded to in relation to the frequency of expressions of PL needs related to resources. When teachers wait for PL providers to take the lead, the assumed roles of expert PL provider and learner are likely to be at play. Although less obvious this same dynamic operates when teachers express their PL needs in written form. Providing generic, brief and ambiguous responses guards against revealing ignorance and the concomitant threat to their identities as competent. As suggested by Beswick and Jones (2011) and Wilson and Berne (1999), relationships in which mutual respect and trust have time and opportunity to develop are key to effective PL. Thirdly, the fact that teachers in the BMTLC project often asked question at the time of the PL that did not necessarily match what they had requested illustrates Wilson and Berne's (2009) point that PL agendas need to be refined in an ongoing process of negotiation.

CONCLUSION

The three projects discussed have illustrated that calls to involve teachers in determining the focus of PL are not asking for something that is straightforward. Calls for relationships between teachers and PL providers and teachers that are characterised by trust are not new but are nevertheless important and especially so when PL is conducted in broader societal and policy environment in which teachers may not feel valued or respected (e.g., Australian Council for Educational Research, 2013; Bland et al., 2011; European Commission, 2012; Hargreaves et al., 2006) or when encouragement for them to engage intellectually with issues of teaching and learning occurs against a backdrop of apparently politically driven change as was the case in the MARBLE project (Watson et al., 2012).

The evidence from these projects is that the kinds of PL needs that teachers tend to nominate are predictable in other ways. Nevertheless, the act of asking teachers about their needs, including facilitating their ability to bring things to mind by providing lists, is, if acted upon, a first step to building trust that may allow teachers eventually to be more open about their needs.

PL providers need to be mindful that change is difficult and emotive and that teachers are fundamentally driven by the need to develop and maintain their professional identity as a competent teacher (Sowder, 2007). When we ask teachers to identify their PL needs we are opening the possibility of challenging them to change their thinking about mathematics and the teaching and learning of the subject. In so doing we are asking them to make changes that may have far-reaching consequences for their identities as teachers and more widely (Chapman & Heater, 2010).

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Approaching Professional Learning: What teachers want

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Abstract: *Teachers do not come to professional learning opportunities as blank slates. Instead, they come to these settings with a complex collection of wants and needs. The research presented here takes a closer look at these wants across five different professional learning settings distilling from the data a taxonomy of five categories of wants that teachers may approach professional learning with. The resultant taxonomy, as well as teachers behaviours vis-à-vis this taxonomy indicate that we need to rethink our role as facilitators within these settings as well as the role that single workshops can play in the professional learning of teachers.*

Keywords: Teacher beliefs; Mathematics teacher professional development; Taxonomy of teacher wants

Introduction

Current research on mathematics teachers and the professional development of mathematics teachers can be sorted into three main categories: content, method, and effectiveness. The first of these categories, content, is meant to capture all research pertaining to teachers' knowledge and beliefs including teachers' mathematical content knowledge, both as a discipline (Ball, 2002; Davis & Simmt, 2006) and as a practice (Hill, Ball, & Schilling, 2008). Recently, this research has been dominated by a focus on the mathematical knowledge teachers need for teaching (Ball & Bass, 2000; Ball, Hill, & Bass, 2005; Davis & Simmt, 2006; Hill, Rowan, & Ball, 2005) and how this knowledge can be developed within preservice and inservice teachers. Also included in this category is research on teachers' beliefs about mathematics and the teaching and learning of mathematics and how such beliefs can be changed within the preservice and inservice setting (Liljedahl, 2010a, 2007; Liljedahl, Rolka, Rösken, 2007). Some of the conclusions from this research speaks to the observed discontinuities between teachers' knowledge/beliefs and their practice (Cooney, 1985; Karaagac & Threlfall, 2004; Skott, 2001; Wilson & Cooney, 2002) and, as a result, calls into question the robustness and authenticity of these knowledge/beliefs (Lerman & Zehetmeir, 2008).

The second category, method, is meant to capture the research that focuses on a specific professional development model such as action research (Jasper & Taube, 2004), lesson study (Stigler & Hiebert, 1999), communities of practice (Little & Horm, 2007; McClain & Cobb, 2004; Wenger, 1998), or more generally, collegial discourse about teaching (Lord, 1994). This research is

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"replete with the use of the term inquiry" (Kazemi, 2008, pg. 213) and speaks very strongly of inquiry as one of the central contributors to teachers' professional growth. Also prominent in this research is the centrality of collaboration and collegiality in the professional development of teachers and has even led some researchers to conclude that reform is built by relationships (Middleton, Sawada, Judson, Bloom, & Turley, 2002).

More accurately, reform emerges from relationships. No matter from which discipline your partners hail, no matter what financial or human resources are available, no matter what idiosyncratic barriers your project might face, it is the establishment of a structure of distributed competence, mutual respect, common activities (including deliverables), and personal commitment that puts the process of reform in the hands of the reformers and allows for the identification of transportable elements that can be brokered across partners, sites, and conditions. (ibid., p. 429).

Finally, work classified under effectiveness is meant to capture research that looks at changes in teachers practice as a result of their participation in some form of a professional development program. Ever present in such research, explicitly or implicitly, is the question of the robustness of any such changes (Lerman & Zehetmeir, 2008).

As powerful and effective as this aforementioned research is, however, it can no longer ignore the growing disquiet that somehow the perspective is all wrong. In fact, it is from this very research that this disquiet emerges. The questions of robustness (Lerman & Zehetmeir, 2008) come from a realization that professional growth is a long term endeavour (Sztajn, 2003) and participation in preservice and inservice programs is brief in comparison. At the same time there is a growing realization that what is actually offered within these programs is often based on facilitators (or administrators or policy makers) perceptions of what teachers need as opposed to actual knowledge of what teachers really want (Ball, 2002). But not much is known about what teachers really want as they approach professional learning opportunities.

The research presented here provides some answers in this regard.

Methodology

As articulated in Liljedahl (2010b), working in a professional development setting I find it difficult to be both a researcher and a facilitator of learning at the same time. As such, I generally adopt a stance of noticing (Mason, 2002). This stance allows me to focus on the priorities of facilitating learning while at the same time allowing myself to be attuned to various phenomena that occur within the setting. It was through this methodology that I began to notice that there was a distinct difference between the groups of teachers that came willingly to the professional development opportunities that I was leading and the teachers that were required, often by their administrators, to attend. This was an obvious observation. Nonetheless, it was as a result of this observation that, I began to attend more specifically to what these differences were. In doing so I began to notice, subtly at first, that the teachers who came willingly came with an a priori set of wants. With this less obvious observation I changed my methods from noticing to more directive research methods. I began to gather data from five different professional learning contexts over a period of two years.

Master's Programs

Teachers in this context are practicing secondary school mathematics teachers who were doing their Master's Degree in Secondary Mathematics Teaching. This is a two year program culminating in either a comprehensive examination or a thesis depending on the desires of the teacher and the nature of the degree that they are seeking. From this group I collected interview data and field notes during two different courses I taught in the program.

Induction Group

This group began as an initiative to support early career teachers (elementary and secondary) as they make the transition from pre-service teachers to in-service teachers. In truth, however, it also attracted more established teachers making it a vertically integrated community of practicing teachers of mathematics. Although this group now meets every second month for the duration of the study we met monthly. From this group I collected interview data, field notes, as well as two years of survey data.

Hillside Middle School

Hillside (pseudonym) is the site of a longitudinal study. For the last five years I have met with a team of three to six middle school teachers every second Wednesday for an hour prior to the start of the school day. This group began as an administration led focus on assessment of numeracy skills, but after the first year took on a self-directed tone. The teachers in this group lead the focus of the sessions and look to me to provide resources, advice, and anecdotal accounts of how I have seen things work in the many other classrooms I spend time in. For the two year period that constitutes the study presented here I collected field notes and interview data.

District Learning Teams

Very much like the professional learning setting at Hillside, district based learning teams are self-directed. Teachers meet over the course of a year to discuss their classroom based inquiries into teaching. This inquiry runs throughout an entire school year, but the teams themselves only meet four to six times a year. The data for this study comes from three such teams that I facilitated in two different school districts. One of these teams ran during the first year of the study, the other two teams ran in the second year of the study. Like at Hillside my primary role is to provide resources, advice, and insights into their plans and reported classroom outcomes. The data from these teams consisted of field notes, interviews, and survey results.

Workshops

During the two years that I collected data for this study I was also asked to do a number of one-shot workshops. These were workshops designed around a variety of different topics either decided by myself or the people asking me to deliver the workshop. They ranged in time from 1.5 hours to 6 hours with no follow-up sessions. Data, consisting of field notes, comes from six such workshops. Data from two additional workshops consists of field notes and survey results.

Field notes in the aforementioned settings consisted primarily of records of conversations I had with individual teachers during breaks as well as before and after the scheduled sessions. I used these

times to probe more specifically about the origins of questions asked, motivations for attending, querying about what they are getting out of the session, and if there is something else they need or want. This sound very formal and intentional, but in reality, this was all part of natural interactions. In all, I collected notes on over 70 such conversations.

More directed than these natural conversations were the interviews. These were much more formal in nature and provided an opportunity for me to probe further about the conversations we had previously had or the things I had observed during our sessions together. Each interview lasted between 30 and 60 minutes. In all, 36 interviews were conducted over the course of the two years, resulting in 26 hours of audio recordings. These recording were listened to as soon as possible after the interviews and relevant aspects of the recording were flagged for transcription.

The survey used with the Induction Group, The District Learning Teams, and two of the Workshops consisted of an online survey instrument that was sent to the teachers prior to professional learning session. The survey contained five questions:

Name?

Where are you in your teaching career? Are you in PDP (please specify semester), a TOC (how many years), on a long term TOC placement (for how long), or do you have your own classroom (for how long)?

If relevant - what grades/subjects are you teaching right now?

What do you hope to get out of our next session together? You can ask for understanding of mathematical concepts, teaching strategies, resources, lesson ideas, ideas about classroom management, networking opportunities, specific lesson plans, etc. In essence, you can ask for anything that will help you in your teaching or future teaching. List as many as you want but please be specific.

Please list something from a past session that you found particularly useful.

The last two of these were of obvious relevance to the study. However, as will be seen later on, question two contributed data that became relevant to the analysis.

The field notes, interview transcripts, and survey data were coded and analysed using the principles of analytic induction (Patton, 2002). "[A]nalytic induction, in contrast to grounded theory, begins with an analyst's deduced propositions or theory-derived hypotheses and is a procedure for verifying theories and propositions based on qualitative data" (Taylor and Bogdan, 1984, p. 127 cited in Patton, 2002, p. 454). In this case, the a priori proposition was that teachers come to professional learning settings with their own wants in mind and that these wants are accessible through the methods described above. With a focus on teachers' wants the data was coded using a constant comparative method (Creswell, 2008). What emerged out of this analysis were a set of themes specifically about the wants expressed by teachers as well as a broader set of themes that cut across these wants. In what follows I present these themes in two distinct sections. The first section is a taxonomy of five types of wants. The second section are the themes that cut across this taxonomy.

Results - WANTS

As mentioned, one of the things that emerged out of the aforementioned analysis was a taxonomy of five distinct categories of wants that teachers come to professional learning settings with. To these I add a sixth category. Although not a want per se this sixth theme deals with the resistance with which some teachers engaged in some of the professional developing opportunities. In what follows I present each of these categories in turn, beginning with resistance and following it up with each of the five categories of wants.

Resistance

In the course of the two years of the study I collected data on a number of teachers who were flatly opposed to being part of the professional development setting I was working in. All of this data consisted of observation and conversations and came solely from the workshops and learning team settings. To a person, these teachers were participating in these settings at the bequest of an administrator or a department head. Left up to them, these teachers would choose to not attend. Their want was that they didn't want to be there.

First, these resistant teachers were present and they did participate in the sessions. They engaged in the activities, they asked questions, and they collaborated with others in the room. But this participation was guided by their reluctance at being there. As such, their contribution to the group was often negative, pessimistic, defensive, or challenging in nature. They would say things like "that will never work" and "I already do that". This is not to say that these teachers were the only ones to utter these types of statement, but rather that they only uttered these types of statements. Their questions to me were always challenging in nature with greater demands for evidence, justification, and pragmatism. These challenges were welcomed as they often provided others with an opportunity to engage in the content more critically. The call for pragmatism, in particular, was not unique to resistant teachers, but the goals for making that call were clearly different. When they challenged ideas based on their infeasibility the goal seemed to be to detract from the value of what was being offered; to invalidate it. When non-resistant teachers made the same call it seemed to be motivated by a goal to try to navigate the space between the ideal and the feasible; to find a way to make it happen.

The second reason I include this theme is that these teachers did not always remain resistant. There were several cases in my data where teachers who initially approached the setting with resistance softened their stance over time. In the workshop settings this was marked by a shift in the types and ways in which they asked questions, the ways in which they engaged in activities and interacted with their peers, and in the parting comments and conversations I recorded. In the learning team settings this was marked by the fact that between meetings, these initially resistant teachers, reported back at subsequent sessions about efforts made, and results seen, in their own classrooms.

The third reason for including this theme here is because I want to differentiate between the resistance a teacher may have to an idea in a professional learning setting and the a priori resistance a teacher may approach that setting with. In the former case I am talking about a healthy form of scepticism that, as mentioned, allows teachers to negotiate the space between the ideal and the real, between the theoretical and the practical. The later, however, is a stance that can prevent the uptake of good ideas and helpful suggestions. It can act as a barrier to learning and professional growth.

In all, out of the 70 conversations that I made notes on, 10 were with teachers who were, at least originally, resistant to being in the setting. Of these, four changed their stance over the course of the setting. However, my field notes record observations of many more such a priori resistant teachers as well as observed changes in some of them.

Do Not Disturb

This category of wants characterizes those instances where a teacher engages in professional learning because they want to improve their practice, but is reluctant to adopt anything that will require too much change. Ideally, what they want are small self-contained strategies, lessons, activities, or resources that they can either use as a replacement of something they already cleanly insert into their teaching without affecting other aspects of their practice. Such wants were rarely stated outright. Instead, they manifest themselves as overly specific statements of what it is they seek.

"I was hoping to learn a new way to introduce integers".

"I want something to do for the first 10 minutes of class."

"A different way to do review."

All of these are indicative of situations where the teacher is looking to improve one thing about their teaching. The "don't let it affect anything else around it" is implicit in the specificity of the statement. In conversations or in interviews, however, this can sometimes come out more explicitly.

"I'm happy with the rest of my fractions unit. It's just division of fractions that messes me up. I was hoping that you could show me a better way to explain it."

Delving deeper it became clear that in many of the instances where concern over disturbance and tight control over impact was important there was an underlying anxiety, most often around the deconstructing what they have worked hard to build up.

"I've been teaching for seven years now, and I'm really happy with the way things are going. After the last curriculum revision and with us getting a new textbook I have worked really hard to organize all of my lessons and worksheets in math. I don't want to mess with that. So, please don't tell me anything that is going to mess me up. I really just want to know if there is a lesson that I can do using computers that will be fun and that I can just sort of insert into my area unit."

Less often this anxiety is around what they have worked hard to understand.

"When I started teaching I was fine with math. But when I was given a grade seven class this year I sort of panicked about math. Especially the unit on integers. I had never understood it when I was in school and it took me a long time to teach it to myself. So, I don't really want to learn anything new that will rock the boat for me."

In other instances there didn't seem to be an underlying anxiety, but just a pragmatic disposition that small change is good. The teachers with this disposition came to the professional learning settings with a want to learn new things and a willingness to make changes, so long as these were small changes. Although only one teacher spoke directly about this "less is more" disposition there was lots of evidence of it in the way teachers spoke about what they got out of the sessions. For example, in an interview after a session on formative assessment, one teacher told me that she had learned "I am not going to give out zeros anymore". Although important, in relation to the larger conversation of the difference between formative and summative assessment this is a by-product of a shifting assessment philosophy, not a change unto itself. However, when probing further it revealed itself that for this teacher "no zero's is something I can start doing on Monday". This was something that she could cleanly insert into her practice.

Regardless of the motivation, the teachers who wanted to make only small changes know what it they don't know, or don't do well, and want to learn new things to help change them.

Willing to Reorganize

A slight nuance on the previous theme is when teachers want very specific improvements and they are willing to significantly reorganize their teaching and resources to accommodate the necessary changes. Although specific in nature, these wants do not come with limitations. They are stated with an implicit openness to the consequences that the desired improvements may necessitate.

"So, yeah. I'm looking for an improved way to have my students learn how to do problem solving. Right now I do it as a unit in February, but it's not working. I've heard that other teachers do it throughout the whole year and I'm hoping to get some ideas around that."

Further probing of this teacher, as well as the others who made similar statements, revealed that they are not hampered by anxiety around invalidating existing resources or undoing things learned. Like their counterparts in the previous category, however, they know what they don't know or what they don't do well and they want to make changes to improve these things. The difference is the scale at which they are willing to make these changes.

Willing to Rethink

Unlike the previous two categories, the wants that fit into this are much broader in scope and often welcome a complete rethinking of significant portions of a teaching practice.

"I'm pretty open to anything. I mean with respect to differentiated learning."

From the interviews it became clear that for this teacher, as well as for those who expressed similar wants, there exists something in their practice that they want to bolster. In many cases these

teachers are wanting collections of resources that they could then organize and integrate into their teaching.

"Anything to do with numeracy is good for me."

"I'm looking for new ideas about assessment for differentiated learners."

In some cases, however, these teachers are branching out into new territories and are looking for a comprehensive package of what to do.

"I'm hoping to introduce the use of rubrics into my teaching and want to get the rubrics I should use as well as instruction how to do it."

Either way, these teachers have a rough idea of what it is they want and are willing to rethink their teaching in order to accommodate new ideas. They do not have the anxieties of disrupting already held knowledge or resources that the teachers in the first category did and their wants are broader in scope than the second.

Out With the Old

The wants in the previous category were characterized by a willingness to rethink significant aspects of teaching practice. In the Out With the Old category, the wants are characterized by a rejection of a significant aspects of teaching practice. Teachers with these wants come to professional learning settings unhappy with something in their practice. This unhappiness goes well beyond the awareness that something needs to be improved that was seen in the previous three categories. For these teachers there is nothing to be integrated, there isn't a replacement of some aspect of their teaching to be made. They have already rejected the current paradigm and are now looking for something to fill the void that is left behind.

"My kids can't think for themselves in problem solving. I don't know what I'm doing wrong, but it doesn't matter. I just need to start over with a new plan."

"I can't stand the way group work has been working in my classroom. Or not working is a better description. I have given up with what I've been doing and am looking to learn something completely different."

This is not to say that these wants are coupled with blind acceptance of anything that fits the bill. The teachers who express these wants are often hypercritical of new ideas, usually as a result of their dissatisfaction with something that they have previously changed in their practice.

"I spent a whole year trying to teach and assess each of the processes [communication, connections, mental mathematics and estimation, problem solving, reasoning, technology, and visualization] that are in the curriculum. In the end my students are no better at estimating or communicating, for example, than they were at the beginning of the year. My approach didn't work. I need a new way to think about this."

This is not to say that they are closed minded, but rather that they exert a greater demand on me, as the facilitator, to bridge the theoretical with the pragmatic.

Inquiry

The final category consists of those wants which align with the ideas and ideals of inquiry (Kazemi, 2008). As such, these wants consist, most often, of a general desire to acquire new knowledge and ideas about teaching. The teachers who express these wants are open to any new ideas and often come to professional learning settings without an agenda.

"I'm not really looking for anything in particular. But, I'm eager to hear about some new ideas on assessment."

This is not to say that these wants are flighty and unrefined. The teachers whose wants fall into this category are often methodical in their change, pausing to ask exactly "what is it I am doing" and "if it's working". And if it is working they question "what is it that is telling me it is working". They want evidence of success, but they want it to come from their own classroom.

Results – cutting across the taxonomy

As mentioned earlier, aside from the taxonomy of wants, there were also a set of themes that emerged out of the analysis which can be characterized as cutting across the taxonomy presented above. In what follows I present each of these themes.

Pseudo-Hierarchy

The aforementioned taxonomy of wants seems to form a hierarchy in the way each category requires a slightly greater openness to change than the previous one. But this can be deceptive. Although the teachers in the more longitudinal aspects of the study tended to have wants that became more and more open as the study went on, there were still days later in the study when they would come into the session wanting something as overly specific as a problem to do with the students the next day. There was also evidence in the field notes of individual teachers changing the scope of their wants within a single session. Sometimes this was a broadening of wants to ones that were more open to changes in teaching practice. Other times they regressed to wanting easily insertable resources, especially when the discussions shifted to tricks and best practices.

Two nuances of this theme are worth noting. The first one has to do with novice teachers. Almost without exception, these teachers came to professional learning opportunities with wants that fit into the willing to rethink category. Deeper probing revealed a very good reason for this – these teachers do not have deeply seated practices to disrupt, they have not yet found things about teaching that they wish to reject, and they have not yet routinized aspects of their teaching to the point where they feel comfortable engaging in inquiry. What this leaves is the category of rethinking practice. Except, with their newness to teaching this often became more of a willingness to think about their practice than rethink their practice. Given that I met many teachers whose wants were in the first two categories this means that time in the field can cause a regression regarding openness to change. This was not surprising, but troubling nonetheless.

The second point worth noting is the fact that although I can, at this point, sit back and challenge the evidence regarding the hierarchical nature of the taxonomy of wants, the data indicates that as a facilitator I was constantly trying to upsell teachers on their wants. That is, I was always trying to create more openness and broaden the scope of what it is they wanted out of their work with me. This was especially true of the teachers who came with wants in the first two categories. And, many teachers did expand their wants as a result of these efforts. There was even evidence in the data my efforts to, and success at, shifting the wants of resistant teachers; although to a much lesser extent than those teachers who came willingly. Although not the focus of this article, this is an important point in that it shows the potential effectiveness of a facilitator in fostering changes. But it also speaks to the fact that teachers who come willingly to professional learning settings are already engaged in thinking about change and, as such, are predisposed to changing.

Engagement

Something that emerged very clearly from the data was that the wants that teachers had coming into a professional learning setting affected the way in which they engaged in the session. These types of engagements can be seen as fitting into three categories.

First, the teachers who wanted to make minimal change tended to manage to extract things from single sessions that spoke of small change. An example of this was presented above in the way one teacher took away from a wide sweeping session on the differences between formative assessment and summative assessment only the one small, and easy to implement, strategy of not "giving out zeros". Other such examples include "having students tell the story of how they solved a problem" as the only tangible thing that came out of a session on improving students' communication skills in mathematics, or "not telling students if their answer is correct" out of a session on problem solving. These examples, almost all coming out workshop settings, are solid evidence that a teacher who is committed to making small change will find ways to make small change, even in the face of complex and broad topics. However, as mentioned above, in the more longitudinal settings of the District Learning Teams or among the teachers at Hillside there was a general trend towards more openness.

The second category pertains to those teachers who approached these professional learning settings already open to change. Unhampered by the need to restrict their changes these teachers were more willing to take on ideas that went beyond the scope of the wants that they came into the professional learning settings with.

"So, I wanted to understand why our district is saying that we can't use zeros anymore. I was willing to make changes around this in both testing and homework if I could figure out what to do instead. Now I realize that what I really need to do is change the way I collect information about my students' performance. I need to get away from the collection of points and focus more on the collection of data."

They were also more willing to walk away from professional learning settings with commitments to make change in areas other than what they came in with.

"I originally wanted to work on numeracy skills, but now I realize that I also need to work on my students' group work and communication abilities."

This was true irrespective of the nature of the professional learning setting. This willingness to take on broader or different ideas than they initially came in with was seen even across very short single workshops. Unlike the teachers who wanted small change, these teachers' openness to change is not limited to what they know they don't know, but extends to what they didn't know they didn't know.

The final category pertains to those teachers who were resistant to participating in the first place. Although there are a few rare exceptions, for the most part these teachers were unaffected by the ideas presented in workshops. Their resistance to being present extended to their resistance to new ideas. But as mentioned, they were still present and they did participate. However, their contribution to the group was often negative, pessimistic, defensive, or challenging in nature. Having said that, the two teachers who were required to be part of a District Learning Team did change over time and both started coming to the sessions with expressed wants that broadened in openness with time.

Autonomy

A final theme that emerged from the analysis pertains to the autonomy of teachers. As mentioned early on in the article the impetus for the research presented here grew out of the obvious difference between teachers who want to be present and those who do not. This speaks greatly to the autonomy I saw exercised not only in the participation on professional learning settings, but also in the way in which the teachers participated. The teachers were free to take up new ideas, or not. They were free to broaden their thinking on new ideas, or not. What drove this freedom was their autonomy as teachers and as learners. Although I presented new things to them they got to decide what they would do with them. They could reject them, they could think about them, or they could act on them.

Among the teachers who I had repeated interactions with, this autonomy extended beyond the professional learning settings and into their teaching. They were free to implement change, or not. They were free to try out new ideas, or not. And again, they exercised this autonomy.

This autonomy is obvious and it didn't take reams of data and deep analysis to see it. What the data and the analysis showed, however, was that the teachers exercised their autonomy in ways that redefined my role as a facilitator of professional learning. Although I was behaving as though I was driving the agenda of professional learning the reality is that at every stage the teachers had their own agenda, that they pursued this agenda, and that they used me as a resource in this pursuit. This is not to say that I did not have influence or that I was not able to change agendas, but rather than at every stage the teachers exercised the ultimate control; they could choose to learn or they could choose not to, they could choose to agree, or they could choose not to. The strongest evidence of this is what brought these teachers to the sessions, sometimes repeatedly. Each time they had a goal for attending—a want they needed satisfied—and they saw me as a resource likely to satisfy this need.

Conclusions

Much can be taken from the results presented above. The most obvious is that teachers come to professional learning settings with a variety of wants and needs. The results indicate that these wants can be organized into a taxonomy with pseudo-hierarchical properties. More importantly, however, is what the results say about teacher autonomy and the role that workshops play in the professional growth of teachers.

It is a long held belief that single workshops are an ineffective means of creating professional growth (Ball, 2002). Although the data indicates that this was generally true for teachers who are either resistant to change or are only willing to make small changes, the results also indicate that this was not at all true for teachers whose wants coming into the session were more open to change. In settings where participation was voluntary this accounted for the large majority of teachers. These teachers were quite willing to not only broaden their thinking on what they wanted out of the session, but were also willing to take up entirely new ideas. These results nuances the way we should view the effectiveness of workshops in facilitating teacher change.

Teacher autonomy, too, is something that needs to be taken into greater consideration. Coupled with the taxonomy of wants the results of this study feeds into a new paradigm in which the professional growth of teachers is seen as natural (Leikin, 2006; Liljedahl, 2010b; Perrin-Glorian, DeBlois, & Robert, 2008; Sztajn, 2003) and teachers are seen as agents in their own professional learning (Ball, 2002). Teachers do not approach their professional learning as blank slates. They come to it with a complex collection of wants and needs and use professional development opportunities as resources to satisfy those wants and needs. Recognition of this has an impact on how we view our role as facilitator in these settings. Working from the perspective of a resource we need to be much more attuned to what it is that teachers want, even if that awareness of the taxonomy of what they could want.

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Facilitating stakeholders: Experiences from the Austrian IMST project

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Abstract: *In this paper, we will present an elaborate example of what can happen, if you give educational stakeholders a chance to participate and even more instigate change processes in a supportive environment. We report on experiences from the Austrian IMST (Innovations Make Schools Top) project.*

Key words: Professional development of teachers; teacher projects; teacher institutes; action research; Austria

Introduction

Many educational systems face the same challenge: Years of research have led to good notions of what might work in a classroom, and even better notions of what does not work. Pilot studies have found promising ways to teach, but those were never taken up large scale and often disappeared once the project in which the teaching methods were explored terminated.

This problem is in itself well known, and moved the field of educational research to engage in organizational studies and consider not only professional teacher development, but its embedding in school and system development. This shift also instigated a shift in the perception of the involved teachers: no longer are they seen as individuals who put what researchers have thought about into practice, but they are seen for what they are: Autonomous subjects, who can drive changes or object to them and hinder them for reasons which may be good or bad depending on their local knowledge and their motivation. Konrad Krainer (this volume) has written on this shift and the resulting perception of teachers as stakeholders.

In this paper, we will present an elaborate example of what can happen, if you give educational stakeholders a chance to participate and even more instigate change processes in a supportive environment. We will also present this environment, the measures taken and needed to support people in following their vision, and in grounding that vision in research. The narrative of this development is a historical one, starting with the “national educational crisis” introduced by the perceived poor performance of Austrian students in the 1995 TIMS study.

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The educational context and the overall conception of IMST

In 1995 Austria took part in the TIMS-study. The results of the high-school seniors were considered poor, and the ministry of education commissioned an analysis of the state of mathematics and science education in Austria. Main findings were that there exist(ed) many promising projects and initiatives, but they were fragmented and not well known (see Krainer, 2003). Thus, many initiatives had to start from scratch, instead of learning from each other and previous dead-ends. There was also a lack of supportive institutions, no professor for didactics of mathematics for elementary schools and also a lack of professors for didactics of the physical sciences. Additionally, one wanted more teachers engaged in reflecting and working on their teaching.

The strategy to rectify that situation was therefore to install a project – the IMST project (“Innovations Make Schools Top”²) – to support teachers with the main tasks to network teachers working on their teaching, as well as to network projects, developments etc., to raise the number of teachers engaged in a reflection of their teaching, and to support those teachers. Thus, the project had two strands : a) a networking strand, which tried to involve teachers and the educational authorities in a region to implement networking and professional development activities in their region, and b) a teacher project strand organized in the form of a fund (the IMST-fund), which supported between 100 and 150 teams of teachers³ to conduct action research projects on an aspect of their own classroom teaching. Additionally, the IMST-team was commissioned to map out a support system for the quality development of mathematics, science and technology teaching.⁴

IMST started in 2000, since then the project was re-commissioned several times (so far till 2012). The project went through various phases: At first, there was a stronger direct involvement of subject didacticians, who themselves worked with teachers alongside expert teachers. Later on, the expert teachers working with the didacticians worked with the teachers by themselves. Over the years the range of addressed teachers was increased: the project started initially to support higher secondary schools only (because of the bad results at the TIMSS upper secondary); after four years lower secondary teachers were also addressed, and finally in 2007 the call for participation was opened for elementary school and kindergarten teachers. In 2010 IMST started to participate in the EU-project Fibonacci, participating in an international exchange on models and strategies of “scaling up” projects to effect system change.⁵ The increase of the target population posed some challenges: Since higher track secondary education is taught at the universities as opposed to the university colleges of teacher education, the subject didacticians were experts for the higher track secondary schools, but had on average little expertise for e.g. elementary school didactics. And for a long time, university colleges for teacher education did not have a requirement for their staff

² (The former name was “Innovations in Mathematics, Science and Technology Teaching”, however, when the subject German language was integrated the project title needed to be renamed to a more encompassing one)

³ The number varies due to the number of submitted project proposals and the project budget. In 2010 the ministry decreased the budget leading to a reduction of supported projects to 100. About another 20 projects were financed by an economic fund.

⁴ A more detailed account of the development of IMST can be found in Krainer (2008)

⁵ This is only one aspect of Fibonacci; in general Fibonacci fosters inquiry based mathematics and sciences education in Europe; scaling-up local initiatives is one important aspect. See www.fibonacci-project.eu.

to be engaged in research (This changed in 2007⁶). Over time, the fund strand developed and revised guidelines of how to support the teachers engaged in the action research projects. A systematic approach to evaluating the project and additional research projects contributed to a growing understanding on the effects of the project and the needs for further development (See Krainer, Hanfstingl, Zehetmeier; 2009; Rauch, Kreis, 2007).

Also, at the beginning there was no regional network structure for mathematics and the sciences in the Austrian provinces. Initially, the team worked with a number of highly engaged schools. Later on, teachers of those schools formed the seed of the developing regional networks.

But all this structure to support teachers and schools is futile, if teachers and other educational stakeholders do not reach out to make use of it to their own ends.

Teacher projects in IMST

One strand of IMST set up a fund to support action research projects done by teachers or teams of teachers. Usually around April a call for application went out to all Austrian schools, asking them to submit project proposals in the fields of mathematics, the sciences and German (mother tongue) classes. The project proposals had to be submitted on-line. Over the years, the IMST-team had put together a detailed questionnaire for the proposal, in which many aspects of the intended project were queried. For instance, it asked about the aims, the classes and projected number of students (split by girls and boys), the number of participating teachers, the intended evaluation, the material needed to purchase etc. Teachers could ask for a budget including support by experts of their choice (the budget requests were carefully screened for their fit with the project and had to be approved of by the IMST team). The information was put in a data-base and used as a guideline to determine the suitability of the project for funding by a team of external evaluators. Since the number of supported project was restricted to a number between 100 and 150 (depending on the national funding), not all suitable applications could be supported. Each year, the external evaluators had to resolve the tension between excellence and supporting learning experiences. Not in all cases the project was already well projected. Concerning projects which seemed interesting in their enterprise for developing new approaches in teaching and learning but lacking in their description, the stance was, that there were people willing to try with a lack of experience of either thinking or of reflecting and writing about their teaching situation and goals. The expectation was that people were aware of the requirements of the project (see below) and that they would acquire some of the lacking competencies in the workshops and through the engagement with the project and the community of other teachers pursuing their projects.

Besides requiring the project application detailing a plan of activities and an evaluation, IMST required teachers to participate in a start-up workshop (usually in the second month of the school year) and additional workshops in which they refined their project plans. These ideas were usually written down and then commented on by the advising IMST teachers, and jointly

⁶ Strictly speaking, the university colleges for teacher education were only installed in 2007, their predecessors were in each region two institutions: the pedagogical academies responsible for initial teacher education and the pedagogical institutes responsible for continuing professional development.

discussed in the workshops. Teachers could sign up for evaluation workshops which introduced basic ideas about evaluation and left room to discuss how to evaluate their specific project with the workshop leaders (staff of the university). IMST also required teachers to submit a project report at the end – this was again commented on and frequently revisions were required, sometimes teachers attended “writing workshops” in April or May to that end. The approved project documentation was then published online (www.imst.ac.at/wiki⁷).

Synergy with a specific support system

That not all children are well served by their schools is a well-known fact leading to additional services of special education in various forms. For Austria, Lorenz and Radatz (1993) found that 6% of elementary students show signs of dyscalculia; another 15% are poor in their mathematics performance and need additional support. PISA 2003 found that 19% of the 15-year olds are at risk in mathematics. In the province of Carinthia in Austria, the national authorities first supported a project and later on installed the special education center “Sonderpädagogisches Zentrum” (SPZ) to support teachers in working with children with special needs in elementary schools, in particular with children with dyslexia and dyscalculia. Teachers working as special education teachers were regular elementary school teachers who got additional education on the state of the art of dyslexia and dyscalculia by federal institutions.

In the province of Carinthia, the government sponsored either one or two special education teachers for each of the ten districts. These teachers had to be asked for by the elementary school teachers, they then came to school and worked for up to one and a half year individually with a child in the afternoon after regular school hours. In addition, they should also advice teachers on dyslexia and dyscalculia.

One of these teachers, responsible for supporting schools and teachers with students with needs is Angelika. The work as a special education teacher being called in, when the regular classroom teacher noted something was off, was unsatisfying to her⁸. Given her background as a former regular classroom teacher together with the new insights provided by the further education on dyscalculia, she found that generally she was called in too late – in third and fourth grade, after an unhelpful number concept had already been acquired. Given her background, she was also convinced that part of the problems could have been avoided by a different teaching approach. After all, international comparison and brain studies suggest that only about 6% of the students may face dyscalculia due to their neurological basis, but that the additional 15% could be avoided by another way of introducing mathematics in elementary school. In other words, while many students might not face problems due to an erroneous number conception later on, a small(er) percentage of students would remain, for whom mathematics would be challenging. But even for those, the experience of mathematics could be less upsetting, or even interesting and positively challenging.

Since part of the duties of a special education teacher involved supporting and consulting teachers, it was not a far stretch to develop a seminar for teachers informing them about new

⁷ The reports of the work of the teachers and of Angelika cited in this article can all be found in the IMST wiki.

⁸ The second author of this article. All teacher names used in this article were changed.

insights in those areas. In 2007, Angelika offered seminars (4 units each) on “Avoiding dyslexia” and another series of seminars on “Avoiding dyscalculia”. After one of these seminars, a participant – Gabriele – came up to her. Gabriele was about to apply for an IMST project, and asked whether the special education teacher could coach her changing her classroom teaching in accordance with the “new approach” in this project. In other words, Gabriele was aware of the IMST project, about to submit a project proposal, and attending the seminar, she found a topic she wanted to pursue, something specific she wanted to change in her classroom and in her mathematics teaching.

Gabriele and Angelika: Their first IMST project

In 2007, Gabriele submitted an application, in order to work with Angelika on her first grade teaching of mathematics and reading (see Zoltan, 2008). IMST approved the project and accepted the budget request for an expert support. Additionally, Angelika’s supervisor at the special education center supported her ultimate intension to prevent or decrease the rate of dyscalculia and dyslexia appearing in the district’s classrooms. She sanctioned Angelika to use one hour a week to accompany the project even though another special education teacher was assigned to the very school Gabriele was working in.

At the same time, as Gabriele pursued an IMST project, a colleague at her school, Otelia, also engaged in an IMST project about experiments in science teaching in her elementary class; both teachers attended the IMST workshops and learnt about each other’s projects. Thus, in the end, four people started to discuss their projects at the school site: the two teachers of the school (Otelia and Gabriele) and the two support teachers of the special education center (Angelika and another special educator).

Gabriele’s project afforded Angelika a chance to work with an engaged teacher to put her ideas into practice. Angelika had been working as an elementary teacher before, but now she needed to coach someone else to implement the changes she regarded as beneficial. In the seminars during the previous school year, Angelika had been teaching Gabriele about dyslexia and dyscalculia and she had distributed further materials on those topics. Additionally, Gabriele had already experience of working with Montessori materials. However, with Angelika she now introduced “learning plans” similar to the Dalton plan as developed by Helen Parkhurst (1922) into her classroom. Learning plans were plans for six to eight weeks of subject learning, detailing the concepts students should acquire, accompanied by materials, work sheets, tasks etc., which students would work on. During this time, students should explore and acquire central concepts, not just practice something which was previous presented by the teacher. Thus, a central tenet of this form of instruction is to strengthen student autonomy, making them from an early age onward responsible for their own learning.

Two units each day were devoted to students working on their plan work. During that time, students would work individually or in pairs on self-selected tasks with the teacher helping or observing individual students. Students were not required to do all and every task, but some tasks should be mastered by all at the end of the six to eight weeks (minimal standards). An important element of teaching with needs of students with difficulties typical for dyscalculia and dyslexia in mind was to support them but also all other students with carefully selected

tasks and questions, specific contrasts etc. This should enable them to quickly find an efficient mathematical strategy and the relevant mathematical concerns, leading the children to discover mathematical patterns they can exploit to their advantage. For instance using sets like in Table 1.

Table 1.

Calculate:

6-1	7-2	8-3	9-4
6-5	7-5	8-5	9-5

It is important specifically for students with difficulties to support them not to lose possibly limited resources of attention and memory on side-tracks. Here, the teacher may actively intervene with guiding questions.

In weekly meetings, Angelika and Gabriele planned the learning environment; they discussed the goals of the units and devised the learning plans. They discussed their classroom observations and individual further support for or needs of specific students. In her IMST report (Kittner, 2009), Angelika observes that during the school-year the teacher decreased in providing information to student queries and began more and more to guide students' own thinking, for example, by posing relevant questions.

Gabriele comments in her report (Zoltan, 2008), that in an individual assessment she did with the students at the end of the school year none of the students made mistakes due to false concepts or inappropriate strategies. She also notes that students differed widely in their competencies, e.g. one student with learning difficulties (as well as with a general delayed development including motor development) took a long time to master some of the concepts.

At the end of the school year, Gabriele had started to radically change her teaching, giving more and more space to her students. She was very satisfied with her new classroom teaching and decided to continue the project the following year in second grade with another IMST project (see Zoltan, 2009). With enthusiasm she inspired other teachers both at her school and at another school also to change their classroom teaching along the same lines.

Angelika had acquired many insights about supporting changes in classroom teaching. For her, the experience validated her beliefs that she should support teachers to integrate insights from dyslexia and dyscalculia into their classroom teaching rather than support them in dealing with problems partly raised from other teaching approaches. At the same time, the individualized learning setting allowed her and the classroom teachers to better support those students who do have (by reasons stemming from other sources than schooling, e.g. neurological differences) more difficulties in mastering those core competencies than other students. She also got convinced that it was important that on top of the seminars she had offered, she (or someone else) would aid the teachers in their change process for first and second teaching. She presented her ideas and the results of this first project to her supervisor and the district's superintendent. When eight teachers asked her to support them during the following year, her supervisor and the district's superintendent endorsed her efforts: she was

granted to use two hours a week for assisting those teachers. Based on this newly won time resource, Angelika installed a monthly quality assurance circle.

The second year: IMST and EVEU

In the following year, five of the eight teachers (of five different schools) participated in IMST working on their classroom teaching. Angelika herself also submitted an IMST project, a so called “Verbundprojekt” (roughly translated: “compound project”). This is a special form of project, IMST institutionalized in order to facilitate collaborative endeavors like this. A “Verbundprojekt” requires a number of project devoted to the same issue, and a further project, which works with all of them, for instance in doing an overarching evaluation, organizing targeted professional development (and documenting and evaluating those efforts as required by any IMST project). Angelika called her Verbundprojekt “EVEU” (Ein veränderter Elementarunterricht – a changed way of instruction in elementary school; Kittner 2009, 2010).

In other words, during the second year, eight elementary school teachers participated in the quality assurance circle, and five of those teachers did an IMST project, working on some aspect of their teaching, evaluating and documenting it. Angelika facilitated the circle. On top of that, given her duty as special education teacher for the district, she could use one of her weekly support hours to aid two of the teachers at Gabriele’s school. She used that time to prepare and discuss materials for the classroom teaching, model the “new” teaching approach, help the teachers to organize the classroom into the new learning environment, to observe the students and teachers and to provide feedback. She also used her time teaching students to allow the classroom teacher to go off and observe another member of the quality assurance circle teaching what they had previously discussed.

The participation of the teachers in the quality assurance circle was voluntary with no compensation, for instance by a reduction of their professional development requirements. The meetings were carefully planned, usually the group decided on a specific topic to address during the following meeting. Angelika took care, that the group remained on task, and used the time in a constructive way. Mostly they worked on making themselves ready for the next learning stage according to the level of difficulty and complexity determined by research on dyscalculia and dyslexia. They prepared materials and tasks, and were greatly aided by the materials already trailed by Gabriele during the previous year. They also discussed their experiences in using the materials, and reflected on what had worked and what did not. The last meeting was devoted to assess the competencies of the students to reflect on what they had learned and also to prepare the stage for the next year. In their project documentation, teachers stressed how important the group was for them “Without the other teachers’ help, we would have been too much on our own. [...] Just the fact that one was talking about the problems appearing over the course of the school year provided some measure of relief and motivated to go on. Often one found a solution in such conversations.” (Zoltan & Thurner, 2009: 14)

The meetings took place in a room specifically organized for these meetings at a local elementary school. In the room Angelika displayed materials, demonstrated how to set up a “learning path” for the students and presented literature.

Gabriele and her classroom was an important agent in that development. She told of her own practices and shared her problems and solutions. Two first grade teachers of her school followed her example (in their own way), being able to build on her experiences.

Parallel to the work with the teachers, Angelika still offered seminars to teachers on avoiding dyscalculia and dyslexia which were well attended showing a need of the teachers. Given her experiences and further feedback of participating teachers, Angelika decided to turn the seminar in a series of four and later five modules, allowing her to go more deeply into the topics and addressing concretely of how to put the insights into dyslexia and dyscalculia into classroom practice.

Further developments

The series of seminars led again to teachers asking Angelika to coach them in putting changes into practice. The following year, she had 12 teachers of various schools participate in another quality assurance circle. The participation in such a circle was accredited as official professional development, counting as fulfilling the elementary teachers’ in-service education requirement.

In 2011, Angelika was coaching three quality assurance circles in her district, and had queries for support from teachers of other districts. Angelika is now in the process of expanding her model to other districts, and to widen the support in her district. She feels that those teachers, who participated in the model, implemented and reflected the changes in their own classroom and took part in the quality assurance circles, could now themselves advise other teachers in particular in their own schools, to implement further changes. At the same time, she strives for the educational authorities responsible for the districts to have their special education teacher also support quality assurance circles, as she deems an ongoing support and reflection of changing classroom practices paramount to any sustainable change.

In 2010 Angelika’s EVEU project won the IMST award⁹ in the special category for projects involving a number of classes or schools, in 2008 Gabriele’s project had won the classroom project award. In each case, the minister of education herself congratulated the winning teams.

Discussion

What made these developments possible? What are the lessons learnt from that development? Let us briefly consider the circumstances that enabled Angelika and Gabriele to go from dissatisfaction with the status-quo to a new practice of teaching and learning and of

⁹ Since 2007 the IMST-award awards three of the IMST projects in each of the two categories mentioned above for outstanding excellence. A jury evaluates each project on a number of criteria including the innovative character, attention to making the subject attractive to students, dissemination, sustainability, consideration of gender issues and careful evaluation.

professional development. The following points (but the first one, which integrates aspects of all three) are organized in line with Krainer's (this volume) three dimensions of aspects important for teachers' learning: Context, Community and Content.

- (a) A number of highly dedicated teachers were engaged in these efforts, in particular during the first two years. However, the seminar attendance showed a high need and a willing of teachers to take advantage of anything worthwhile, even if it takes time and effort. Some teachers of the second year stressed in their reports that it was important that there were materials already out there, they could take away, that they did not have to develop everything from scratch. The situation was different during the first year; here Gabriele and Angelika had much less to build on. Thus, in the beginning, the project needed a few highly dedicated hard workers, who developed the materials, and put them into practice. Yet, given research on innovations (Everett, 1965) it is to be expected that some teachers will be willing to take the first steps. It is more difficult to get more people to participate, however, as in the presented development the work-load decreases with the number of experienced teachers who are willing to share their experience and materials, the prospects are positive.

Context

- (b) In all cases, the principals and supervisors were very supportive, not only allowing the teachers to take time to participate in continuing development but being actively encouraging. This stresses the importance of the leadership of principals as put forward by Krainz-Dürr (1999, 2006).
- (c) Likewise the educational authorities were very supportive with time granted to work on the project and active financial support for materials etc. We find that – at least in Austria – the educational authorities are usually interested in effecting (positive) change as long as it is relatively cost neutral. In the presented case, the predominant cost factor was the time Angelika spent in various classrooms and in supporting teachers. This was within the scope of her work requirements, even though it meant a re-framing of her task from addressing determined problems to preventing problems (as far as possible).

Community

- (d) While the developments needed dedicated practitioners in a supportive environment, Angelika also considers IMST as pivotal in the developments. With IMST, the teachers working with Angelika pursued their own projects, according to the funding philosophy. This implies that while the teachers worked with Angelika, they were nevertheless in charge of their project and their classroom development. IMST did not require them to consult this (or any other) expert, and to work with him or her. In other words, the environment of IMST places Angelika and the teachers as equal partners, and left – with respect to the documented project – the teachers in authority. The teachers were responsible for their projects and had to write their reports. Even though Angelika had a clear vision of what she wanted to achieve, IMST held the teachers responsible for their own projects, and discussed their projects and their documentation directly with them.

- (e) At the same time, IMST served in the capacity of a quality assurance institution – asking for a project plan, a budget plan, requiring evaluation and documentation. However, IMST did not direct the way the project went or ask for particular topical considerations. IMST expert teachers advising the project may have offered suggestions, and may have provided further literature and thoughts, asking teachers for reflection on some topics. But they would not require them to pursue an active (instead of reflective) role in following up one of their suggestions.
- (f) Through IMST and in particular the workshops, teachers met other people engaged in projects; in the particular case two teachers at the same school working on different ideas started to discuss their ideas in (and out of) the workshops. The common task of “project management” in a shared framework of requirements (and accounting) afforded a joint interest and supported the development of a continual exchange.
- (g) Angelika’s work placed her in a singular context – as a special education teacher working for the district she was well educated. To uphold the quality of her work, she was and needed to be in constant contact with the institute for learning difficulties in mathematics providing her with up to date information and literature. She as an expert needed an expert institution, a community of experts, to turn to herself.

Content

- (h) An important element of IMST is the requirement of writing up a project report. For many teachers this is a difficult task (see also Schuster 2008). However, in the end the “Verbundprojekt” EVEU could draw on six teacher reports and the report of Angelika herself. This provided a further basis for presenting the project to interested parties like the educational authorities, Angelika’s supervisor etc. and to elicit further support. Few teachers and other educational personnel have experiences in writing up their insights and ideas. IMST also provides a support structure for writing reports and reflective discourse on instruction. Teachers may attend writing workshops, submit various drafts and get feedback; they learn how to present themselves and their ideas. We think that this is an often underestimated aspect of classroom change: (effective) classroom practices needs to be communicated to spread and communicated well and not only verbally. IMST afforded the teachers and Angelika to work on the presentation of their ideas to be suitable to be convincing others.
- (i) Content-wise the project offered an up-to-date approach to teaching mathematics and reading skills for elementary school teachers. This enabled teachers to teach and students to learn two core subjects of elementary school in a consistent way. Since this article is addressed foremost to the mathematics education community, we want to stress that it is questionable whether students’ active participation in their learning of number concepts would work as well, if they encountered a different participatory positioning in their language classes. If we want to effect changes in elementary classroom, we believe we need to integrate the subjects with respect to didactical stances.

In brief, there are many factors and elements which enabled EVEU to grow. But EVEU is not the only project started by teachers and dedicated educational support personnel that expanded to something larger (see Hanfstingl, Krainer, 2008, Schwetz, 2007, Haider, 2009). Educational stakeholders can and will effect instructional change if given the possibility. For

that they need projects like IMST, which do not narrowly direct the change processes but leave space for the concerns of stakeholders, which provide the means to call in experts and cover other expenses, and which nevertheless care for and also actively support the quality of the change processes and their documentation. They also need expert institutions which provide expert consultations (at no costs to the schools) to facilitate an up-to-date understanding and knowledge of the situations under concern. Then, we may put our trust in stakeholders to increase the stakes.

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Teachers as Stakeholders in Mathematics Education Research

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Abstract: *In this paper, we report on our experiences with professional development at the Calgary Girls School in Alberta, Canada. In particular we reflect on factors such as mentoring and teacher coaching that contribute to higher student achievement as well as a culture of co-operation and collaboration in the context of the Alberta Initiative for School Improvement (AISI).*

Keywords: Mathematics teacher professional development; Calgary Girls School; Alberta Initiative for School Improvement; mentoring; teacher coaches; Galileo Educational Network Association

Background Information on the Calgary Girls School

The Calgary Girls' School is a public charter-school in Calgary, Alberta, Canada that was founded in 2003. The school consists of 600+ students in Grades 4-9 across two campuses who come from a wide range of socio-economic, religious, and academic backgrounds. The school places great emphasis on the extensive use of collaboration as a strategy between and among parents, girls and staff. The collaborative culture that has been established over numerous years at the Calgary Girls' School is based largely on the work of DuFour (2005) and the creation of Professional Learning Communities.

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The Calgary Girls' School seeks to enhance girls' confidence in their abilities, particularly in the areas of mathematics, science, and technology. The mathematics program at the Calgary Girls' School places value on depth rather than breadth, the justification of solutions obtained using multiple problem-solving approaches, the use of concrete materials and pictorial solutions as a means of conveying understanding, collaborative learning amongst students, and the identification and exploration of the authentic applications of mathematics. Teachers of students entering the Calgary Girls' School spend much time revising students' perception that they are lacking the ability to do mathematics. The structure, focus, and intent of the math program at the Calgary Girls' School owes much to the influence of Hanson (1992), Pettitt (1995), Gutbezahl (1995), and others. Moreover, teachers at the school are very familiar with the work of John Van de Walle, and have developed their teaching practice in the area of mathematics thanks in large part to his influential teacher resource, "Elementary and Middle School Mathematics".

Introduction

What follows is a written reflection from the perspective of two mathematics teachers who in December 2011 completed a four-day workshop focused on the professional development of in-service mathematics teachers at all grade-levels, excluding post-secondary education. Over the course of these four days, a number of mathematics education researchers, professional development facilitators, and professional mathematicians spoke about their successes and struggles in implementing professional development with mathematics teachers in their respective countries. In hearing from the various presenters, a number of thoughts came to mind regarding the various types of teacher professional development that we, as teachers, have received thus far in our professional teaching careers.

In this paper, we address several key points: 1) the importance of relationship between PD facilitators and teaching staff to the success of professional development initiatives, 2) the manner in which a collaborative professional learning community built on trust allows for teachers to take risks necessary for significant professional growth to take place, 3) the importance of accessing teacher input when determining possible directions for professional development, and 4) our experience with a province-wide professional development initiative known as the Alberta Initiative for School Improvement. We also discuss the importance of the presence of a teacher coach on our teaching staff, as well as the significant influence that an individual in this role can have on the growth and professional development of new teachers.

The importance of relationship

Teaching is highly personal work. The various lessons and units of study created by teachers consist of the teacher's own thoughtful ideas and creative approaches to taking up curriculum. By consequence, there is a tendency for teachers to take criticism of their work from those outside of the school quite personally, perhaps even shutting down when such criticism comes across as too harsh. We would differentiate criticism from critique, the former considered to be feedback provided by those without a strong personal stake in the learning of the students and the latter being feedback focused more specifically on instruction than the teacher themselves. It is our belief that by first addressing what is strong in a teacher's work, whatever that may be, there is a greater likelihood that teachers will develop a trusting relationship with those they are working with and be open to the ideas being shared with them.

It is our belief that relationship is first and foremost to being a good teacher. If there is not a relationship present between teacher and student, then learning is less likely to occur.

Students, both young and old, need to feel safe in their learning surroundings and believe that their teacher is fully invested in knowing each individual they will be working with; this includes understanding where the student is coming from, what they know, what they want to know, and what they do not know.

In order to cultivate a collaborative and supportive environment, it is essential to build relationships between teachers and math educators. The deepest learning in the classroom often exists when the teacher-student relationship is a focus and the same can be said for the teacher-PD facilitator relationship. Listening to the teachers' perspective in order to truly understand where the teacher is starting from and to build on the strengths of the individual are critical to the success of this relationship. It is also important for the teacher to know and understand the underlying goals and theories behind any PD educator's approaches.

Culture of Collaboration and Trust

Upon starting a career at the Calgary Girls' School one of the important draws is the administration's recognition that every teacher, regardless of the number of years of experience they bring with them, is in a place of learning. In fact, the administration team at the Calgary Girls' School makes it clear to new graduates of teacher-education programs that their first year at the school could be viewed instead as their 3rd year of their 2 year education program. There is an implicit understanding that the attainment of perfection in one's teaching practice is not expected nor is it reasonable to anticipate. The administration wants all teachers, regardless of years of experience in the classroom, to always ask questions and engage in dialogue with co-workers. Teaching at the Calgary Girls' School does not exist in a closed room in isolation. Instead, teachers are grouped in grade teams supported by specialist teachers, support staff, and

administration. There isn't a day that goes by when there is not a conversation in the hallway or in a team meeting about curriculum, various tasks or individual student needs. At the Calgary Girls' School, teachers have a collective goal as a group, and that goal is to educate students to the absolute best of the teaching staff's collective abilities.

In order for professional development initiatives to take hold, our view is that teachers must belong to a collaborative working environment where support is provided from colleagues and administrative staff alike. The process of altering one's teaching practice takes time and can certainly place a teacher in a challenging professional space. To change one's teaching practice also requires support from colleagues and open communication about the struggles one is experiencing in implementing the specific teaching practices shared with teachers through professional development work. A culture of collaboration and openness allows teachers to share their concerns with one another and uncover what is and isn't working, then initiate the types of solutions recommended through professional development projects.

There is a culture of collaboration present throughout the Calgary Girls' School. When potential teachers interview for teaching vacancies at the school, they are told outright about the expectation placed on teachers to collaborate. Teachers are required to meet on a weekly basis with the other members of their teaching team to plan collaboratively in creating interdisciplinary inquiries. Collaboration is an expectation of not only the administration, but the teaching staff, as well. Teachers at the Calgary Girls' School hold one another accountable. If a fellow colleague brings forth an idea, teachers work as a team to bring the idea to an even higher level. Teachers discuss the relevance of the task, the formative/summative assessment, the underlying reason behind pursuing such a task, the ways in which teachers will fully engage (hook) the students into the topic or inquiry being pursued. By consistently asking themselves,

what is worth knowing, why should students care about a topic?, and why people fall in love with a given topic, teachers at the Calgary Girls' School do much to create engaging projects and inquiries through collaborative work and dialogue with colleagues.

Example #1: Teachers Seeking Subject-Specific Support from Colleagues

Teachers at the Calgary Girls' School come into the teaching profession with a wide-range of undergraduate experience, completed prior to pursuing degrees in education. As such, there are teachers on staff with a wide-range of basic expertise in fields ranging from Fine Arts, Entomology, Political Science, Earth Science, to Biology, and so on. Teachers on staff at the Calgary Girls' School are made aware of the range of expertise accessible within their own ranks and are encouraged to both pursue and lend such expertise when in need.

At the Calgary Girls' School, it is not uncommon for teachers of a particular subject or grade to seek assistance from another staff member who possesses sought-after expertise. For example, one year, a Grade 9 mathematics teacher was hoping to explore the concepts of congruence and similarity of polygons with his students by having them create some geometric art-work. While this teacher felt confident with the mathematics behind this work, they felt much less confident in choosing a medium for the work or understanding what would be required of one who chooses to create a geometric piece of art. This teacher knew that one his colleagues in Grade 8 had a background in Fine Arts, and so, dropped by their classroom to request assistance. The Grade 8 teacher proceeded to compile a list of images of various geometric abstractions she had studied and even re-created in her undergraduate studies, which she then forwarded over to the mathematics teacher, along with some suggestions for a possible medium to work with and techniques to apply with this project.

This sort of experience is commonplace at the Calgary Girls' School and occurs both within and across grade-teams. If teachers are pursuing a larger-scale project, time is afforded to them by the administration to exit their classrooms and join other teaching teams with the intent of lending their particular expertise.

Example #2: Teachers Seeking Support Regarding Teaching and Learning from Colleagues

At the Calgary Girls' School, teachers not only lend the expertise they garnered during the completion of their undergraduate degrees, but also the teaching expertise they acquired from their previous years teaching. The vast majority of teachers at the Calgary Girls' School have experience teaching several grades, which is a result of the administration's policy of switching teachers from grade-to-grade. By consequence, teachers can lend the expertise they gained from teaching a previous grade to the current teachers of that grade.

For example, during our cycle III AISI project regarding hands-on science, the two Grade 9 mathematics/science teachers were granted their request to spend a day working with both a former Grade 9 teacher and a Grade 5 teacher, both of whom possessed a wealth of knowledge on the concepts from the Grade 9 Electrical Principles unit. These four staff members were granted one full day to congregate in the school science lab to play with and create series and parallel circuits, motors, generators, fuses, and lemon cells, etc. On this day, the teachers with previous experience teaching electrical principles shared all that they knew with their less-experienced colleagues, who also had the time to explore the concepts to be uncovered in this unit and overcome the anxiety they had been feeling in preparing to teach this challenging science unit. The Grade 9 teachers who took part in this in-house professional development day

not only left with a greater sense of confidence in their ability to teach this unit, but also a vast array of possible lessons and activities to implement in their classrooms in the coming weeks.

Example #3: Vertical Planning and Collaboration

Vertical planning has proved to be an excellent space for collaboration and professional development within our school. One concrete example of this experience is focused around the exploration of the Cartesian plane. A need arose out of a grade four classroom to utilize graphing as a tool to make sense of a set of collected data. In order to pursue this concept, the grade four teachers decided to ride the wave of energy generated by the students and stop their current exploration of patterns in order to investigate graphing. Through discussion and conversation with our “teacher coach” and a fellow colleague who taught grade nine it became evident the exploration in the grade four classroom was essential for the development of knowledge in the grade nine classroom. What was realized, through discussion and access to a teacher coach who was joining the discussion within each grade team, was there was a gap in our students’ learning surrounding the plotting of co-ordinate points on a Cartesian plane. The recognition of this gap informed the grade four teaching teams’ planning and exploration of the concept of graphing. “Why do we use graphs?”, “what are graphs?”, “how do we graph data?”, and “what story will graphed data tell?” were just a few questions the teachers began to explore with their grade four students. In order to effectively graph their collected data, the students needed to develop the skills of plotting co-ordinates on a grid. Concurrently the grade nine classes were exploring tessellations and translations of shapes on a co-ordinate grid. The constant dialogue between the teacher coach and the teachers of each respective grade, allowed for authentic and rich exploration of a concept and idea across the grades.

Example #4: The Sharing of Planning Documents Amongst Staff

It would not be uncommon to see a teacher at CGS notice a great rubric or activity on the photocopier and grab a copy for themselves. The culture of sharing our work with colleagues is pervasive throughout the school. In fact our school has adopted the use of Intelligence On-line (IO) as our whole school planning tool. Created by the Galileo Educational Network Intelligence On-Line is a web-based professional learning environment created to provide support to teachers in their planning.

“The foundation of IO is an inquiry-based approach that opens doors to powerful learning opportunities. Inquiry begins with a meaningful problem, issue or topic. Students build new knowledge as they work through intriguing tasks. They solve problems, uncover issues and rigorously test their discoveries and they learn to use technology to think in new ways.” (Intelligence On-Line).

Utilizing this on-line tool teachers share each of the projects designed by their teams with one another. While a particular person might start the project and have it listed under their name, these projects are not owned by any one individual. As we do not work in isolation, none of our tasks or activities exist solely because of one teachers voice. Whether we have just switched the grade we teach and are uncovering curriculum for the first time, or we are exploring the same concept across the grades such as the Cartesian plane, asking for support or resources from our fellow colleagues is not only supported it is expected. In addition to the on-line planning tool which supports teachers in the design process of a rich and rigorous inquiry, IO also provides

space for discussion with colleagues and experts regarding the topics of exploration, thereby extending the circle of collaboration beyond the walls of the school.

“The IO community is made up of thousands of professional educators designing great projects. Anytime you run into a roadblock, you can communicate with your own personal network of IO members; or collaborate with the community to share, give input or receive feedback.” (Intelligence On-Line)

Teacher Voice in the development of PD

We believe that the form of professional development that is most fully embraced by a teaching staff appears to come about in response to the needs of teachers; needs identified by teachers and communicated to their administrators. Teachers view themselves as professionals capable of assessing the learning of their students and creating engaging activities that do well to develop students' understanding of relevant learning objectives. While they may not formally engage in the process of educational research, teachers do make observations of learners and learning on a daily basis. As such, teachers have much to contribute to the conversation around teaching and learning, and are eager to share their thoughts on these topics. It is our belief that teachers are less likely to pursue professional development initiatives that have been created for them in response to a need identified by administrators or a resource from outside the school. Teachers need not necessarily be consulted regarding the forms of professional development they would like to pursue, but would appear to be more likely to pursue professional development initiatives when such consultation takes place or when such initiatives are teacher-driven.

Alberta Initiative for School Improvement

At the Calgary Girls' School, teachers have taken part in numerous professional development activities that met this standard. The Calgary Girls' School has taken part in the past three cycles of the Alberta Initiative for School Improvement or AISI. AISI provides funds to schools to develop and pursue professional development plans intended to foster student engagement and advance teachers' professional practice (Alberta Education, 1999). Our school had the fortunate experience of benefiting from AISI projects. With each cycle of the project lasting 3 years, CGS has been involved in 3 full cycles, each with a different focus.

The first cycle of AISI at the Calgary Girls' School (AISI cycle II) focused on developing teachers' abilities as mathematics educators in a middle school setting. This was one example of a sustained long-term professional development opportunity that was continually evaluated throughout the 3 year duration of the project. As teachers who entered the school in both the final year and the first year after the "Math AISI project" the learning and engagement regarding the teaching of mathematics was still incredibly evident to us. As new teachers we were brought into the dialogue and discussion regarding math education even after the project was complete, through one-on-one sessions with administration, teacher-led examples of what problem-centered math education could look like in the classroom, provided supporting resources (specifically, Elementary and Middle School Mathematics by Van de Walle), and on-going dialogue. As new teachers we felt as if the first AISI cycle at the Calgary Girls' School was alive in the classroom and among teachers regardless of whether it was still a school wide focus.

The second cycle (AISI cycle III) focused on developing teachers' abilities to teach science with a hands-on approach. Specifically, the project description read: "Engage students

through inquiry-based learning, scientific experimentation, hands-on activities and projects and provide teacher professional development through the use of coaching experts, research and assessment for learning.”

Our “Hands-on Science” AISI project is an excellent example of PD that was sustained, consistent and revisited throughout the three years of the project. This particular project came from a recommendation by Alberta Education following an evaluation of our school. Science teaching and learning was identified as an area of growth for our school. This recommendation was brought forth to the teaching staff by the administration, however instead of telling us that this was our next goal and outlining exactly what our PD was going to look like, the administration invited dialogue and discussion surrounding our new goal. The fact that as teachers we were invited into the creation of our science AISI goal, helped us feel as though we had ownership and a voice in the project, thereby supporting our own engagement in the learning.

Our project purpose: To improve achievement, understanding of Science concepts and interest in scientific inquiry for girls in grades 4-9.

Improvement Goals:

1. To improve girls’ learning and achievement in Science
2. To improve student achievement in Science through building teacher capacity in the teaching of Science.

As teachers we were provided any resources we deemed necessary to propel our work in science to the next level. The professional development opportunities included but were not

limited to:

- professional development days with science experts where teachers were provided with several hands-on challenges and guided through them with the assistance of these experts, -days spent planning and “playing” with concrete materials with the assistance of other members of the teaching staff who had experience teaching concepts at hand,
- time spent at science professional development sessions offered by local science teachers through the Calgary Science Network.

Coined “AISI” days, time in grade teams or discipline teams provided to teachers played a significant role in our ability to benefit from the project. Being given “time to play” with the idea, concept or material provided space for teachers to truly engage in the discipline, to enter the terrain we want students to enter. As teachers we become the learner and therefore find ourselves in a position where we can understand the perspective of the student and thereby deconstruct the experience, thereby preparing us to engage with the students in meaningful and authentic ways.

At the outset of our second cycle AISI project, the administration of our school invited several experts in science education to come and work with our staff. In year one of AISI cycle III, each teaching team met with Dr. Sharon Friesen, a faculty member at the University of Calgary with a lengthy background as both an educator and teacher educator.

During these meetings, Dr. Friesen assisted teachers in each team in creating engaging, rigorous, and hands-on activities to be pursued with students in the team’s respective grades. Dr. Friesen played a significant role in developing our teaching staff’s confidence in their ability to teach science with a hands-on approach, due in part to her vast knowledge-base and creative approach to teaching.

Perhaps more important than Dr. Friesen's expertise in the area of science education, however, was her unique ability in creating open, trusting, and constructive relationships with the teachers she works with. Dr. Friesen begins each session with a given teaching team by first listening to their plans then acknowledging the strengths in the work being shared. Dr. Friesen is particularly skilled in implementing professional development due to both her willingness to investigate the history of the school and teachers she is working with, as well as her view that professional development should be focused on building on strengths, rather than remedying weaknesses.

As teachers working with Dr. Friesen, it was evident to us that she viewed teachers as playing a pivotal part in their professional development pursuits. From working with Dr. Friesen, it became apparent to us that she values teachers' ideas and unique qualities, and makes every effort to incorporate, rather than mute, their voices. Dr. Friesen's ability to create and foster relationships with the teachers she works with has made her a very welcome member in our school community and a trusted voice who can be turned to when teachers find themselves in need of assistance.

We could also argue that our work in hands-on science learning, also supported our work in mathematics as many of the skills developed regarding student engagement were definitely transferable. As teachers, simply reflecting on our own comfort level as a science teacher provided ample evidence to suggest that this project was very effective. In order to further evaluate our progress, admin provided teaching staff, parents, and students with questionnaires intended to gauge the confidence teachers had in teaching science, as well as student perceptions of their abilities as scientists proceeding each year of the project. There was notable increase in

students' confidence in their abilities as scientists, notable increase in teachers' confidence in their abilities as science teachers. As well there were significant increases in student performance at the Grade 6 and Grade 9 levels on provincial achievement tests, particularly regarding the percentage of students who met the standard of excellence on these standardized tests.

Qualitative Results following the 3 year cycle: 2008/2009 School Year

Teacher Measures:

2008/2009 Results:

- 100% of CGS teachers are strongly confident in teaching science from an inquiry-based approach
- 97% of CGS teachers report that they are very confident in their knowledge and understanding of interpreting the science curriculum into rich hands on science experiences
- 97% of CGS teachers report that they are confident in their ability to create strong assessment tools in science

Teacher Comments:

"AISI funding has allowed the school to obtain resources that have improved my teaching. In addition, we have the time to plan within our teams to design rich hands-on learning experiences for our students."

"This past year has really supported my ability to teach Science. I learned that I had to take the time to play and be a scientist myself in order to generate excitement within students."

Student Measures:

2008-2009

- 80% of CGS students think of themselves as scientists
- More than 90% of CGS students see themselves contributing to new knowledge in science using an inquiry approach

Student Comments:

"I enjoy the fact that we try hand on experiments instead of only using books to find out what we need to know. We get to be the scientists and try everything for ourselves."

"The part of science that I enjoy the most would be the hands-on work and experiments that we get to do. I enjoy being able to see all of the scientific theories in action. When I experiment with science hands-on, it gives me a greater understanding of the topic."

Parent Measures:

2008-2009

- 81.9% of parents report that their daughter has demonstrated increased understanding in science
- 74.1% of parents see their daughter improving in science
- 73.6% report that their daughters interest in science has increased

PAT Results: Over 2 years of the cycle**Grade 6 2007-2008**

Measure (from project plan)	Baseline	Target	Actual
% of students meeting the acceptable standard in grade 6 Science.	94	97	94.8
% of students meeting the standard of excellence in grade 6 Science.	21	27	28.7

Grade 6 2008-2009

Measure (from project plan)	Baseline	Target	Actual
% of students meeting the acceptable standard in grade 6 Science.	94	97	98.9
% of students meeting the standard of excellence in grade 6 Science.	21	27	36.6

Grade 9 2007-2008

Measure (from project plan)	Baseline	Target	Actual
% of students meeting the acceptable standard in grade 9 Science.	86	92	89.9
% of students meeting the standard of excellence in grade 9 Science.	14	21	24.7

Grade 9 2008-2009

Measure (from project plan)	Baseline	Target	Actual
% of students meeting the acceptable standard in grade 9 Science.	86	92	98.8
% of students meeting the standard of excellence in grade 9 Science.	14	21	52.5

Teacher Coach:

It is our contention that teachers, especially those in their beginning years, would benefit a great deal from having access to an in-house teacher coach or mentor. Too often, teachers are thrust into their profession with little formal support in place. By modeling lessons for teachers and providing them with feedback on their work, as well as suggestions for how to successfully differentiate instruction, mentors could certainly provide novice teachers with much-needed professional support.

For much of its existence, the Calgary Girls' School employed a part-time teacher coach and mentor. This teacher coach was a classroom teacher with 10+ years of experience teaching various core subjects, as well as fine arts, to many different grade levels. The teacher coach's primary responsibility consisted of making scheduled visits to the classrooms of novice teachers to observe their teaching. The teacher coach also met with novice teachers during their prep times to share feedback from the observations they had made, share strategies for differentiating instruction, discuss the process of report-card writing, and assist with the preparation of engaging learning activities in each subject area.

The teacher coach also did much to develop novice teachers' emerging understanding of concepts they were required to teach. One novice teacher who was struggling with the challenging concepts of trigonometry scheduled a meeting with the teacher coach to discuss and develop their comprehension of this difficult concept. At the outset of this meeting, the novice teacher discussed the confidence they had in applying a procedural understanding of trigonometry in order to successfully solve problems, while at the same time acknowledging their lack of a sufficient understanding of sine, cosine, and tangent ratios. The novice teacher had

no idea why $\tan 45 = 1$, but wanted to know in order to both satisfy their own curiosity as a learner and to better serve the students they were going to be teaching in the coming weeks. The teacher coach, who had previously taught the concept of trigonometry to her own class of Grade 9 students, began to draw a series of different-sized right-angle triangles with legs of equivalent length and explain why the concept of the tangent as a ratio of the opposite and adjacent sides in a right-angle triangle. Further work on various right-angle triangles enhanced the novice teacher's understanding of trig ratios and resulted in a significantly better instruction of these concepts to their students. It should be noted that the teacher coach was not only available to work with the novice teacher in developing their understanding of trigonometry, but was also extremely appreciative of the novice teacher's willingness to acknowledge their lack of understanding of this challenging concept in mathematics. Moreover, the novice teacher knew prior to seeking assistance from the teacher coach that such an admission of ignorance would be welcomed by the teacher coach, as the teacher had been informed on numerous instances preceding this experience that teachers at the Calgary Girls' School are expected to continually develop their professional practice, regardless of the number of years of teaching experience they possessed.

Conclusion and Future Directions

Experiencing professional development in our school has certainly shaped the teachers we have become. Ultimately, we believe we have benefited from some of the most effective, long term, revisited and authentic professional development a teacher could ask for. We owe a huge thanks to Dr. Sharon Friesen and the Galileo Educational Network for their support and guidance throughout our journey as developing teachers. As well, we need to identify that the philosophy

and research our school was built upon have played a significant role in creating the community of trust and collaboration you find among all staff within the school. It is through these collaborative spaces that we have learned from both each other and the many mentors who have been invited into our school.

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Professional development: Possibilities and restrictions for mathematics teachers in lower secondary school in Iceland

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Abstract: *Mathematics teachers in many parts of the world have been facing many challenges in recent years. In Iceland teachers in lower secondary school have been implementing a new reform oriented curriculum. Many researchers claim teachers need considerable support if they are to meet the demands of the current reforms in mathematics education. This paper explores whether mathematics teachers at lower secondary level in Iceland are given good opportunities to develop professionally during the last five years and if not what can possibly be done to improve the situation. My conclusion is that the opportunities given are limited and do not meet features that characterize effective professional development. That specially applies for duration and coherence which are considered very important features along with, focus on content, active learning and collective participation. The organisation and funding of professional development in Iceland does not seem to allow for continuation and progression. One important step to deal with this problem would be to make it easier for teachers to attend courses at the universities and to arrange courses in such a way that teachers and student teachers can collaborate and form a learning community.*

Keywords: Mathematics Professional development; Icelandic teachers; Constraints; Organization of Professional development; Iceland

INTRODUCTION

According to the OECD –Teaching and Learning International Survey (TALIS) 22,4 % of teachers in lower secondary school in ICELAND took no part in professional development activities during the last 18 months and 48,5% took part in activities that lasted for less the 11 days. When asked what prevented them from more participation 47,2% of those who mention a special reason say that there was nothing on offer that suited them (Ólafsson & Björnsson, 2009). This inspired the present investigation on professional learning opportunities given to teachers in lower secondary school in Iceland since 2005. The year 2005 is chosen as a starting point due to the reason that from 1999-2005 the main focus of professional development programmes in mathematics was on teachers in grades 1-7. In that period mathematics teachers were implementing new teaching materials for the primary level.

Mathematics teachers in lower secondary school in Iceland have been facing many challenges in their work during the last 10 years. In February 1999 a new National Curriculum Guide in Mathematics was published by the Ministry of Education in Iceland. It is a reform oriented curriculum under the influence of NCTM standards (Bjarnadóttir, 2010). The main change in this new curriculum was that goals for mathematics were divided in to two categories, goals for mathematical processes and goals for content (Menntamálaráðuneytið, 1999). For the first time mathematical processes were given special attention in an Icelandic curriculum guide

with an emphasis in the curriculum for equal attention to mathematical processes and mathematical content. The curriculum guide was revised in 2007 but only minor changes were made. A new reform oriented curriculum makes the teaching of mathematics more demanding as it calls for new competencies on behalf of the teachers and different instructional practices (Kilpatrick, 2004; Niss, 2004).

In Iceland the National Centre for Curriculum Material (NCEM)¹ provides schools with teaching materials aligned with National Curriculum Guidelines. Due to limited funds and lack of manpower (qualified authors) the publisher was not able to publish materials for all grade levels at the same time. The changes in the curriculum also called for progression and coherence in dealing with new content and instructional approaches and therefore it was considered best to start by renewing the teaching material for the lowest grades and then build on that. The publication of a new series of teaching materials in mathematics for grades 1-10 started in 1998 and it ended in 2008 (Gunnarsdóttir & Pálsdóttir, 2010).

Teachers were to implement the new curriculum in three years but little support was given to teachers to accomplish that task and new teaching materials for lower secondary school aligned with the new curriculum guide for grade 8-10 were published until 2005-2008.

The new teaching materials for lower secondary school, *Átta-10*, are very different from the Swedish textbook series, *Almenn stærðfræði* that had been in use since 1987 (Bjarnadóttir, 2010). According to Halldórsdóttir (2008) the Swedish materials build on teaching methods linked to behaviourism with emphasis on procedures, worked examples with lots of similar exercises to follow and self tests to assure that the students have mastered the required skills. Very little attention is paid to mathematical reasoning and communication (Valverde, Bianchi, Wolfe, Schmidt, & Houang, 2002). The teaching materials *Átta-10* build on different ideas about teaching and learning mathematics. In the new materials more emphasis is put on inquiry where students recognize problems, ask questions and look for solutions in cooperation with each other and the teacher. The students are encouraged to develop their own solution strategies, share and discuss them with others. The authors pay special attention to the mathematical processes and one of their main goals is to assist teachers to change their instructional practices towards a more reform oriented teaching) (Bjarnadóttir, 2010; Gunnarsdóttir & Pálsdóttir, 2010).

According to Cooney (2001) the current reforms in mathematics education are characterized by an instructional style in which more time is spent on conceptual understanding and problem solving. Reform teaching also involves more communication and creation of mathematical communities instead of telling and showing. It is therefore challenging for teachers to move from the traditional mode to the reform mode (Cooney, 2001). Many teachers in lower secondary school in Iceland have not specialized in mathematics and mathematics teaching and therefore it is important that they get some support when implementing a new reform oriented curriculum.

¹(<http://www.nams.is/Languages/English-information/>)

In this paper I will explore which opportunities Icelandic teachers in lower secondary have had since 2005 to take part in formal and informal professional development. I use formal professional development as professional training organized by a recognized institution in the form of post graduate education, action research or professional development courses. Informal professional development refers to participation conferences, seminars, reading groups and short workshops and presentations.

I will compare this with what is known from research about effective professional development strategies and models for mathematics teachers. I will also explore how professional development in general is organized in Iceland and to which degree it supports or hinders good professional opportunities for mathematics teachers.

- Are mathematics teachers at lower secondary level in Iceland given opportunities to develop professionally and if not what can possibly be done to improve the situation?

WHAT IS EFFECTIVE PROFESSIONAL DEVELOPMENT?

During the last decade mathematics teachers in many countries have been struggling with implementing new reform oriented curricula. This has been challenging for the teachers. They have both had to deal with teaching new content areas and also to change their instructional styles to more process oriented styles with emphasis on inquiry, conceptual understanding and problem solving (Cooney, 2001). The aim of the reforms and of improved instruction is usually linked to increased student learning. It is also argued that teachers need considerable support if they are to meet the demands of current reform movements. Teacher opportunities to learn and develop their professional knowledge have therefore become central issues in the educational debate. Some scholars even claim that the education reform is often synonymous with teachers' professional development (Desimone, 2009; Sykes, 1996)

Teachers have many opportunities for professional learning both within formal professional development settings such as courses and in-service days and informal settings such as common planning and discussion of lessons, self reflection and reading of professional journals (Borko, 2004; Desimone, 2009; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009). Wei et al. (2009) "*conceptualize professional learning as a product of both externally-provided and job-embedded activities that increase teachers' knowledge and change their instructional practice in ways that support student learning. Thus, formal professional development represents a subset of the range of experiences that may result in professional learning.*" Easton (2008) argues that professional development will not always lead to professional learning and that it is not enough just to develop, educators need to learn and therefore she claims that professional development needs to be replaced with professional learning. Even though I agree with this view I will in this paper use the professional development for all opportunities available for teachers to increase their professional learning both the formal activities and the more informal settings as this is what is done in most literature on teachers' professional development.

Several researchers have tried to point out some principles for effective professional development by synthesizing results from various research and development projects (Borko, 2004; Desimone, 2009; Loucks-Horsley, Stiles, Mundry, Hewson, & Love, 2010; Wei, et al., 2009)

Wei et al. (2009) define effective professional development as development that leads to improved knowledge and instruction by the teachers and improved student learning. They draw on research from both the US and abroad that links student learning to teacher development. In their report *Professional Learning in the Learning Profession: A Status Report on Teacher Professional Development in the United States and a Abroad* Darling-Hammond, Wei and their colleagues put forward four main principles for designing professional learning:

- Professional development should be intensive, ongoing, and connected to practice.
- Professional development should focus on student learning and address the teaching of specific curriculum content.
- Professional development should align with school improvement priorities and goals.
- Professional development should build strong working relationships among teachers. (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009)

They also indicate that other factors like school-based coaching and mentoring and Induction programs for new teachers are important and likely to increase the effectiveness of teachers. They also point out that intensive professional development rooted in practice is most likely to change teaching practices and lead to increased student learning.

Loucks-Horsley and her colleagues have for more than a decade worked on professional development and in the third edition of their book *Designing Professional Development for Teachers of Science and Mathematics* published in 2010 they review new developments in the knowledge base for professional development and use it to enrich the basic principles of effective professional development they presented in their earlier work.

According to Loucks-Horsley et al. (2010) the principles that are present in quality professional development experiences are:

- Effective professional development is designed to address students learning goals and needs.
- Effective professional development experiences are driven by a well-defined image of effective classroom learning and teaching
- Effective professional development experiences provide opportunities for teachers to build their content and pedagogical content knowledge and skills and examine and reflect on practice critically
- Effective professional experiences are research based and engage teachers as adult learners in the learning approaches they will use with their students.

- Effective professional development provides opportunities for teachers to work with colleagues and other experts in learning communities to continually enhance their practice.
- Effective professional experiences support teachers to deepen their professional expertise throughout their career and serve in leadership roles
- Effective professional development experiences provide links to other parts of the education system
- Effective professional development experiences are continuously evaluated to ensure a positive impact on teacher effectiveness, student learning and the school community (Loucks-Horsley, et al., 2010).

It is clear that these principles are very broadly focused and there is an emphasis on linking professional development to teaching practice and student learning. It is also evident that the establishment of professional learning communities is seen as important. Professional learning communities seem to play an important role in supporting teachers in continuously improving their teaching and sustaining their professional learning. (Fernandez, 2002; Loucks-Horsley, et al., 2010) Lesson study is referred to as an example of a professional development strategy that has many of the aspects that characterize effective professional development. Lesson study enhances teachers' knowledge and quality teaching, it develops leadership capacity and the building professional learning communities (Loucks-Horsley, et al., 2010).

According to Desimone(2009) there is a consensus among researchers on the main critical features of professional development that can be linked with changes in teachers practice and knowledge and to some degree in student learning. She points out five main features. They are focus on content, active learning, coherence, duration and collective participation. According to Desimone there is strong evidence that focus on content and how students learn that content in professional development can be linked to teacher development and to some extent to student learning. Active learning where teachers engage in various activities like observations, reviewing of student work and discussions is also an important feature. Teachers also need to feel there is coherence between their beliefs and knowledge and their experiences in professional development and between reforms and policies at all levels. Collective participation and duration are also very important features. Teachers need time to work with, reflect on and try out new ideas and they need to do this in a learning community with others dealing with the same issues. For Desimone these features (*focus on content, active learning, coherence, duration and collective participation*) become the basis of a framework for studying the effectiveness of professional development. She considers the content focus on teacher learning among the most influential ones based on many different kinds of studies(Desimone, 2009).

The critical features Desimone points out seem to capture the core in principles for effective professional development both Darling- Hammond et al. (2009) and Loucks-Horsley et al. (2010) present.

They also have much in common with what Borko, Koellner, Jacobs & Seago (2011) claim is the shared view of many teacher educators on professional development. According to this view professional development for teachers should be a collective endeavour, it should be about the work of teaching and the learning opportunities should be situated in the teachers practice.

Gunnarsdóttir (2002) studied a professional development program in Iceland. It was a two year program for teachers in grade 1-10 in one school district with 7 schools and 240 teachers. The study was based on interviews with 21 teachers who took part in the program. She identified four critical features that aided to the success of the program. Firstly the project encouraged collaboration and provided opportunities for collaboration between teachers. Secondly, courses were organized in a way that it gave teachers opportunities to develop their understanding of mathematics and mathematics teaching and learning. In addition it also provided them with a safe environment to implement ideas in their practice and reflect on their experiences to further develop their own mathematical understanding as well as understanding of their students' thinking. Thirdly, there was an organizational support, the school district and principals all invested in the program and provided teachers with support to participate in the program. And finally, the program spanned over two years (Gunnarsdóttir, 2002). These four features have much in common with the critical features of professional development suggested by Desimone (2009). In my analysis of the professional learning opportunities given to Icelandic teachers in grades 8-10 from 2005-2011 I will use the features from Desimone.

THE ORGANISATION AND FUNDING OF TEACHERS PROFESSIONAL DEVELOPMENT IN ICELAND

Iceland is a small country with 319 090² inhabitants. To put things into perspective it is necessary to provide some basic information about the Icelandic school system and its financial background. Local authorities are responsible for the operation of a 10 year compulsory school for children from the age of 6 – 16. In 2010 the total number of students in compulsory schools was 42929, the number of teaching positions was 4791 and the total cost for running the compulsory schools was 56 billion IKR (487 million UDS)(*Skólaskýrsla 2010*). In 2011 the Icelandic state allocates 199.9 million IKR to compulsory schools and 69,3 million of those funds go to continuous education and school development. The state also gives 423,2 million to publication of educational materials for compulsory schools("Fjárlög fyrir árið 2011,").

According to the salary agreements between the teachers union and local authorities teachers in compulsory school should spend up to 150/126/102 hours a year (depending on age and holiday rights) for professional development and special preparations for their teaching outside their traditional yearly working schedule. The professional development should be under the supervision of the principal and in accordance with the schools professional

² October 1st 2011 (<http://www.statice.is/Statistics/Population>)

development plan. The principal can *ask* individual teachers or groups of teachers to attend specific a professional development activity. Teacher's professional development activities can be divided into two parts, activities that are considered necessary for the school and activities that the teacher finds important for him/herself.

Individual schools and local authorities are responsible for funding teachers' professional development but they can seek support from different channels. In the following an overview is given of the funds that support teacher's professional development, their policy and how they are financed.

Continuous Education Fund

The Ministry of Education allocates a certain amount each year to a Continuous Education Fund a managed by The Association of Local Authorities in Iceland. In 2011 the fund got 22.7 milljon IKR (197000 USD) which is a similar amount as in previous years. Those who want to provide professional development opportunities for teachers, school councillors and head masters in the compulsory school can apply for money to the fund for instance local school authorities, schools, teacher education institutions, associations and firms (Fjárlög fyrir árið 2011)

School development fund

Each year the Ministry of Education allocates money to a school development fund. The aim of the fund is to support development and innovation in pre schools, compulsory schools and upper secondary schools. In 2011 the fund got 46,6 milljons IKR (405000 USD). The Ministry sets some priorities for applicants each year like assessment, democracy, creative thinking, literacy and connections between school levels. Mathematics teaching and learning has not been among the priorities during the last five years and only two projects with focus on mathematics have been supported during that period. Only headmasters of schools can hand in an application on behalf of schools, groups of teachers or individual teachers. Others have to be in a partnership with schools The fund is managed by the Research and Development Centre at the University of Akureyri.

Project and education fund managed by the Teachers Association (KÍ)

The main goal of the fund is to support the professional development of teachers, student councillors and head masters in compulsory school. Employers pay monthly 1,72% of regular salaries into the fund. Members of the Teachers Association and the Headmasters Association can apply for the money in the fund.

They can apply for:

- Support to attend courses, conferences and to go on study trips
- Support for (formal) further education at university level
- Group support to go on study trips to schools and institutions
- Support to local and special organisations of teachers to for instance to pay for professional lectures at annual local teacher conferences in the autumn

- Support to individual teachers or groups of teachers for research and development projects
- Paid study leaves up till 12 months

In 2010 the fund spent 403 milljon IKR on these purposes. 31% went to paid study leaves for teachers or head masters, 25 % to research, development projects, professional courses and study trips (1/3 went to support teachers who are attending post graduate education) and 44% to support to teachers to attend courses, conferences and study trips (Verkefna- og námsstyrkjasóður FG og SÍ: Ársskýrsla 2010).

Most local school authorities have also allocated some funds for professional development to the schools. In 2004 it was estimated that this added up to 83 milljon IKR (Mennta- og menningarmálaráðuneytið, 2010) During the current financial crisis this post that has been cut down drastically by many local authorities. In the City of Reykjavík the schools with 1480 teachers got 24 milljon IKR for this purpose in 2008 but in 2010 and 2011 they got nothing. In Fjarðarbyggð a municipality with around 90 teachers the schools get 1,8 million (20 000 per teacher) for professional development in 2011 which is 2/3 of what they got in 2008. In Hafnarfjörður the schools (both pre and compulsory schools with around 1000 employees) get 5-6 million for this purpose which is a similar amount as in previous years.

PROFESSIONAL DEVELOPMENT OPPORTUNITIE FOR MATHEMATICS TEACHERS IN LOWER SECONDARY SCHOOL IN 2005-2011.

In this section I provide an overview of formal professional development opportunities given to teachers in grades 8 – 10 since 2005. It is based on data from the University of Iceland, School of Education, The Continuing Education section at the University of Akureyri, Reykjavík University, reports from funds awarding money to professional development, information from Flötur the Association of Mathematics Teachers, the city of Reykjavík and other available sources. It cannot be guaranteed that this is a complete overview but it should give a good picture of the situation.

University of Iceland

A special institution *Símenntun, Rannsóknir Ráðgjöf* (SRR) (*Lifelong learning, Research, Consultancy*) has been operating within the School of Education offering service like professional development to schools. The institution is partly self-financed. The institution offers course at set dates at the university campus, assists individual schools and local authorities in planning and applying for funding for professional development activities and operates a webpage with description of various professional development activities that members of faculty have to offer and that can be tailor-made to the needs of schools, local school authorities or others. Courses offered by SRR do not give the teachers any university credit points but they give the teachers an opportunity to fulfil some of the yearly requirements for professional development.

Courses at university campus.

At University of Iceland campus in Reykjavík a course called *Teenagers and mathematics* for teachers in lower secondary school was on offer. The focus of this course was to introduce to

the teachers new teaching materials Átta-10 (the first book in the series was published in 2005) based on the 1999 reform oriented National Curriculum Guidelines and to encourage teachers to develop their own teaching plans with the aid of the new materials but taking into account their own students needs and situations. Emphasis was on instructional approaches like inquiry, discussions, problem solving and hands on activities as well as the teaching of certain content like algebra, geometry and fractions. Different assessment methods were also introduced and teachers were given time to discuss and work on their teaching plans together. The first course was a 15 hour course in the spring 2005 spread over four afternoons. The course was attended by 20 teachers from different parts of the country.

Upon request the course was repeated in the autumn. Here the teachers who were implementing the new materials were encouraged to try out ideas presented in the course with their students and report back on their experiences during the next session. This course was attended by 15 teachers and most of them came from area surrounding Reykjavík.

A third course of the same structure was on offer during the autumn of 2007 but was not carried out as intended because of very few applicants. The few applicants were invited to take part in informal meetings (free of charge) with the instructors. This resulted in 6 meetings where 5-7 teachers met with the instructors and got some input and shared their experiences and ideas.

Instructors at these courses were teacher educators at the university who also were the authors of the new teaching materials for grades 8-10. The participants pay a fee of approximately 150 dollars for a 12 – 16 hour course.

In June 2007 SRR offered a workshop on the teaching and learning of algebra for teachers in grades 6 -10. The focus of the workshop was how to develop numeracy and symbol sense and it was given by Abraham Arcavi, professor at the *Weizmann Institute of Science in Israel*.

In the spring 2010 The University of Iceland and SRR arranged a course in the use and development of teaching materials for the mathematics software GeoGebra. The course was on offer for both university students and practicing teachers and gave the students 5 ECTS³ credits. The course was held on seven Saturdays from January to April. It was attended by 15 practicing teachers.

Tailor made courses for local authorities

Teacher educators at the University of Iceland have developed several courses for mathematics teachers in lower secondary school in cooperation with SRR and local school authorities. They assist in writing course descriptions for applications to the Continuous Education based on request from the local authorities. The requests from the local authorities are usually rather general and they are mainly about supporting the teachers in implementing the curriculum and the new teaching materials.

³ A full academic year of studies is 60 ECTS-credits (European Credit Transfer and Accumulation System).

The timeframe for these courses is usually 1-2 days carried out in August before the start of the school year. The teachers come from different schools in the area. The focus of these courses has been similar to the course given at the university campus. Courses of this type were offered by the local school authorities in Reykjanesbær (2006), Suðurland (2006), Akranes (2006), North East Iceland (2006, 2008), Borgarbyggð (2007), Mosfellsbær (2007), Höfn (2007), Snæfellsbær (2009). A majority of math teachers in these areas have attended the courses. The courses have been paid by the local authorities and in most cases they have been financed with money coming from the Continuous Education Fund.

University of Akureyri, Continuing Education

The University of Akureyri has a Continuing Education section. They offered courses for mathematics teachers in lower secondary school in the area in 2005 and 2006. They were developed and carried out by the teacher educators from the University of Iceland and had a similar focus and content.

Reykjavík University

In 2008 Reykjavík University offered two courses that they called workshops for mathematics teachers. The objective of these courses was to give a theory-based opportunity for professional development for Icelandic mathematics teachers. They were 15 – 20 hours workshops carried out over a period of 4 days. The first workshop was in August before the start of the school year and the second one after school hours and during a weekend in the end of September. The focus of the workshops was effective teaching strategies based on research on classroom practice. The instructor was guest lecturer in mathematics education at Reykjavík University who in his Ph. D. Study had compared classroom practices in Finnish and Icelandic classroom. These courses were free of charge for the teachers.

Other professional activities for mathematics teachers organized by local school authorities or others.

In 2010 the *The Division for Primary and Junior Education* in The City of Reykjavík held a 5 hour workshop for mathematics teachers. The focus of the workshop was the 2007 National Curriculum Guide in Mathematics. Instructors were teacher educator from the University of Iceland and an editor of the 1999 National Curriculum Guidelines in Mathematics and a teacher in a compulsory school in Reykjavík with M. Ed. in mathematics education. The workshop was funded by the Continuous Education Fund.

In 2007 local school authorities in Selfoss and Akranes offered a course on teaching number fluency and arithmetic with direct instruction and precision teaching. It was a one day course given by a teacher and a behaviour analyst. Both courses were funded by the Continuous Education Fund.

Flötur: The association of mathematics teachers in Iceland has been arranging a two days seminar for teachers at all school levels every autumn. At these seminars well known international experts in mathematics education have been giving lectures and workshops for teachers as well as local experts and practicing teachers. In the last five years Richard Noss, John Mason, and Jo Boaler have been among the invited experts at these seminars. The seminars have been attended by 50-100 teachers at all grade levels and it is often the same

teachers that come year after year. The number attending the seminars has been declining. The conferences have been financed by contributions from continuous education funds for compulsory and secondary school teachers and by fees (150 dollars) paid by the participants. Most teachers get refunds from their schools or their professional development fund but some pay themselves.

In association with the NORSMA (The Nordic Research network on Special Needs Education in Mathematics) conference in 2009 a pre conference workshop for teachers was given⁴. It was a 4 hour workshop where both Icelandic teachers and researches and international researchers worked with teachers on representations, outdoor teaching of mathematics, mathematics in games and plays and cognitive variability (60 teachers from all grade levels attended the workshops. The workshop was free of charge due to Nordic funding of the conference.

Included in this overview are only activities that last for at least 4 hours. Teachers have had various opportunities to attend lectures or workshops of a shorter duration held at seminars arranged by teachers associations, universities, The NCEM, schools and others.

Qualification programs

As mentioned above teachers do not get any university credit points for attending professional development courses offered to them by professional development providers like the universities or local school authorities. In order to gain credits teachers have to attend post graduation programs like a Masters program or special qualification programs set up by the authorities in order to raise the level of specialized knowledge of qualified teachers. Both Reykjavík University and the University of Iceland have offered Masters programs in mathematics education and the Ministry of Education has supported special qualification programs for mathematics teachers during the period under investigation here.

Master programs in Mathematics Education

The University of Iceland offers a master's program in mathematics education. The programme is organized as a combination of campus and distance education program with 5-6 days of instruction at campus for each 10 ECTS course. Practicing teachers who have specialized in mathematics during their initial teacher training can enrol in the studies either as full time or part time students. Obligatory courses in the studies are courses on theories and research in mathematics education, on curriculum and competence development in mathematics and one course in pure mathematics where students can choose a course on real numbers and real functions or a course on algebra and linear algebra. Among other elective courses is a course on the history of mathematics and courses on research methods and educational theories. On average 5-8 teachers have enrolled in the programme each year since its start in 2004 and 8 students have finished a Masters degree in mathematics education.

Reykjavík University offered a master's program in mathematics and didactics from 2005-2008. The last enrolments were in 2008. It was organized as a two year program with

⁴ (http://stofnanir.hi.is/norsma/pre_conference_workshops)

instruction in the afternoon enabling practicing teachers and others to take part in the program. Requirement for enrolment was a Bachelor's degree in any subject. The studies consisted of courses in both mathematics and didactics with an emphasis on a problem based approach. In total 32 graduated from the programme but it can be estimated that around 50 students in total took some of the courses in the programme. Those who graduated were not all certified to teach in schools (compulsory or upper secondary) due to different backgrounds.

Specialisation in Mathematics and mathematics education for practicing teachers

In 2005 the Ministry of Education initiated a qualification programme for teachers in lower secondary school who had been teaching mathematics for some years without having specialized in mathematics during their initial teacher education. They were offered to take courses in mathematics and mathematics education at a Bachelor level at Iceland University of Education (Now University of Iceland, School of Education) in total 50 ECTS during a period of two years. The courses were similar to courses given to regular student teachers who specialized in mathematics teaching and organized as a mixture of campus and distance education so that they could be attended by practicing teachers. Around 50 teachers enrolled into the programme but many dropped out due to a heavy workload and only 8 finished the studies in 2007. Five of the others took several courses and one finished in 2008. This programme was free of charge for the teachers and those who lived more than 200 km from the University campus could get the travel costs refunded. The Ministry gave a special support to the University for these studies.

In 2006 on the occasion of the publication of new Mathematics Curriculum Guidelines another programme for the same group was supported by the Ministry of Education. Based on the experiences from the programme in 2005 the teachers who applied took part in a 6 ECTS preparatory course. It started with a 12 hour preparatory workshop where the new Mathematics Curriculum Guidelines were presented and their implications for teaching in compulsory school. The teachers got an opportunity to discuss which support they felt they needed for implementing the curriculum. The workshop was followed up by a course in mathematics and mathematics education which was based on an analysis of the teachers needs. After the preparatory course the teachers could attend courses of their own choice at all universities offering courses in mathematics and mathematics education for a period of three years in order to attain 30 ECTS credits in total. This programme was also free of charge for the teachers and those who lived more than 100 km from the University campus got some travel support. In mathematics 6 teachers have finished the 30 ECTS credits and 34 have finished the preparatory course and several have also taken some courses at the universities mostly at the University of Iceland, School of Education.

Analysis and discussion

The previous section provides an overview of formal professional activities offered to teachers in lower secondary school teachers from 2005 – 2010. In this section they are analyzed according the framework suggested by Desimone (2009) for studying the effectiveness of professional development. According to her there are five critical features

that characterize effective professional development. These features are focus on content, active learning, coherence, duration and collective participation.

It is evident that most of the professional development opportunities described above have a strong content focus both mathematical knowledge and pedagogical content knowledge. Many of them are directly linked to implementation of new curriculum and the aim is to support the teachers in this task. Requests from local authorities reflect both a need for support in teaching new content and in using different instructional strategies.

The national curriculum guide for mathematics and the new teaching materials for lower secondary school put an emphasis on active learning on behalf of the pupils and investigative approaches and mathematical processes are at the core (Bjarnadóttir, 2010; Gunnarsdóttir & Pálsdóttir, 2010). If teachers are to engage their students in active learning they have to experience that kind of learning themselves. This has been an important feature of many of the professional development courses given (and in mathematics teacher education in general in Iceland).

When it comes to the features duration and coherence the situation is different. All specially designed professional development courses are very limited in scope. The courses have typically been one or two day workshops and only given to each group of teachers once. This is due to limited funding. The money allocated to professional development activities by the funds supporting these activities is limited and funds are only given for one year at a time. Courses are also usually held just before the start of the school year or during teacher preparation days at the beginning of the school year. Since most courses involve teachers from more than one school it is difficult to find time for teachers to meet for a course during the school year. It is evident from research on professional development that courses of this structure and length are not likely to have much impact on teachers practice. They can serve some purposes like providing information about new trends and materials but they are not likely to have any impact on teaching practice (Loucks-Horsley, et al., 2010). There are indications that to make an impact on teaching practice and student learning professional development opportunities must to be of much longer duration (30 – 100 hours) and be spread over a longer period of time for instance a whole school year (Darling-Hammond, et al., 2009; Loucks-Horsley, et al., 2010; Wei, et al., 2009).

For teachers taking part in qualification programs like master programs or other programs aimed at raising the level of specialized knowledge on mathematics education among qualified teachers the situation is different. Such programs should at least in principle secure duration and coherence since they are planned as a sequence of courses over a longer period of time (2-3 years).

Many of the specially designed professional development courses encourage collective participation. Teachers from different schools in a municipality or area meet for the course and even though they are of short duration they give teachers opportunities to collaborate within schools and across schools. This is especially important since many of the schools in

Iceland are small (62 out of 152 schools with lower secondary level have less than 50 students). It is therefore not possible to create professional learning communities for mathematics teachers inside the schools. The teachers need to find ways to collaborate across schools and professional development courses and workshops can create such opportunities even though they are of short duration.

Experiences from different structures of qualification programs also indicate the importance of collaboration and creation of learning communities among the students taking part in these programmes. At Reykjavík University the Masters program was organized in short modules concentrating on one subject at a time requiring students to meet and work together four afternoons during the week. At the University of Iceland students at Masters level take 1-3 courses (10 ECTS each) per semester and the studies are a mixture of distance and on campus courses where students meet at campus for 5 days for each course. Most of the students are part time students perhaps only attending one or two courses each semester so they do not form a group taking courses together. Reykjavík University graduated 32 students with a Masters degree from 2005-2010 and the University of Iceland 8 students while the number of students enrolled in the programmes is estimated to be similar. Even though the two programmes are different in many respects it is worth considering the different structure of the programmes and the different possibilities for collaborations created within them and its impact on the number graduated.

This also applies for the difference between the programmes giving practicing teachers opportunities to increase their knowledge in mathematics and mathematics education. On one hand the program starting in 2005 where the teachers were treated like one group throughout the program and given courses similar to courses given to regular students but organized to meet the needs of practicing teachers and the program starting in 2006 where only the first course was specially designed. In spite of big dropout the first program resulted in 13 teachers finishing 30 – 50 ECTS during a period of three years but the other resulted in 6 teachers finishing 30 ECTS during a period of four years. The group from 2005 formed a strong group and they created smaller groups on regional basis that met and worked together. Many of these teachers are now enrolled in post graduate studies or are leading development projects in mathematics in their schools. In the second program the teachers, after finishing the preparatory course, selected different courses on individual basis and took part in the regular distance program with teacher students and had limited opportunities to collaborate with other practising teachers. The fact that the teachers who started their studies in 2005 (those who did not drop out) were treated like a group throughout their studies seems to have had a positive effect on their professional development.

Conclusion

When analysing the professional development opportunities mathematics teachers in lower secondary schools have had during the last 5-6 years it seems clear that the short duration of courses and lack of coherence are the main problems. The funding system does not allow for long time planning and progression of courses. The limited number of mathematics teachers

in lower secondary schools (an estimated number is (Ólafsson & Björnsson, 2009) 300) also sets some restrictions to what can be on offer.

There is a growing concern about the organisation of teachers' professional development opportunities among teachers, teachers unions, the education authorities and the professional development providers. Teachers do not gain anything in the form of higher salary by participating in professional development unless they finish a master's degree. Before 2001 teachers got credit for taking part in formal professional development which resulted in higher salaries when they reached certain amount of credit points. Today they have to fulfil some requirements for PD but often they feel there is little on offer or at times that do not fit their working schedule (Ólafsson & Björnsson, 2009).

In 2009 the Ministry of Education appointed a committee to make some suggestions about how to reorganize the continuous education of teachers at all school levels. The members of the committee came from the Ministry, the teachers unions, the Association of Local Authorities and the Universities that educate teachers.

The committee voiced some concerns about the organisation of professional development and whether this met the needs of the school system. One special concern was the provision of content specific professional development. Here the committee felt there was a need for further work on analyzing the needs of teachers and on making a joint policy. Another suggestion was to make all offers for professional development more accessible for teachers by creating a web page with information about what is on offer at all school levels as well as information about prices and funding. The committee also pointed out the need to make it easier for practicing teachers to attend courses at the universities. Teachers who want to take courses at a university usually have to apply formally to a study programme and pay registration fees each year (Mennta- og menningarmálaráðuneytið, 2010). The universities have a variety of courses that could be of interest to practicing teachers and often they are both on offer as campus programs and as distance education. It has to be made easier for teachers to attend such courses.

Opening up more opportunities for teachers to attend courses at the universities seems to be an important step to make it possible for teachers to attend professional of longer duration and to secure more depth and progression in their studies. But this is not likely to meet fully their needs to collaborate with other practicing teachers and create learning communities. It is therefore also important that the universities design courses that meet the needs of teachers to collaborate with other teachers and study together. Such courses should also give the teachers ECTS credit points they can use if they choose to enter a formal study program later and to document their formal professional development. The universities can also offer other types of courses, workshops and seminars and support developmental work but such activities are less likely to meet all the criteria for effective professional development unless they are combined with other strategies for professional development. But they can serve other purposes like informing on new educational materials and developments, contribute to the shearing of ideas and establish contacts between schools and individuals.

Even though the universities can provide valuable opportunities for professional development it is also important that schools individually or in cooperation with others can design their own professional development projects based on their needs. To make such activities more effective the funding organisms must allow for more long time planning and allocate more money to each project on the expense of number of projects funded each year. This is especially important during the present economical situation where the schools themselves can add very little to the money provided by the funds. In 2011 the Continuous education fund gave the compulsory schools 2424000 IKR to 162 projects during the school year 2011-2012 which means on average 150000 per project (1300 US Dollars). The tuition cost for 1 hour professional development course can be estimated to be 100 – 150 US dollars so what can be done for this amount is very limited.

Another important issue is the time teachers have to participate in professional development. Regardless of which approach you choose for instance to attend courses at universities or take part in activities organized at local level teachers need time to engage in the activities. Making time for professional development is according to Loucks-Horsley et al. (2010) one of the critical issues in designing professional development but not only making time is important but also how it is used. More money allocated to each project might make it easier for schools to free some time for professional development. It should also be possible to find time for professional development within the yearly working schedule of teachers. According to information from OECD Icelandic teachers spend 34% of their yearly working hours (1800) on their teaching in class (OECD, 2011). With good planning, some flexibility and perhaps fewer projects to engage in at a time it finding time should not be a big problem.

Even though there though there are challenges in organizing good professional development opportunities for mathematics teachers in Iceland it should be possible to make the offers more effective without making any fundamental changes to the system at hand. The main challenge in mathematics education is to provide content specific opportunities that are of considerable duration and allow for progression and coherence. With some flexibility and collaboration between all parts this should be possible.

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The others' voice
Availing other disciplines' knowledge
about sustainable impact of professional development programmes

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Abstract: *This paper deals with the sustainable impact of innovations and professional development programmes. While research on this issue is rather scarce in educational disciplines (and in particular in mathematics teacher education), some other domains like health care or development aid are well grounded in research results regarding this topic. This article gives an insight into the other disciplines' knowledge concerning the impact of innovations and professional development programmes and the respective fostering and hindering factors. Moreover, possible implications for (mathematics) teacher education are discussed.*

Keywords: Mathematics teacher professional development; sustainability in professional development; Mathematics teacher education; Models of professional development; Inter-disciplinarity in professional development; Austria

Introduction

The study of educational innovation over the long run is a depressing one.

(R. Slavin)

The question of how to promote mathematics teachers' professional development is of great interest and discussed in various papers (e.g., Krainer & Zehetmeier, 2008; Loucks-Horsley, Stiles, & Hewson, 1996; Maldonado, 2002; Sowder, 2007; Zehetmeier, 2010; Zehetmeier & Krainer, 2011). Ingvarson, Meiers, and Beavis (2005) state: "Professional development for teachers is now recognised as a vital component of policies to enhance the quality of teaching and learning in our schools. Consequently, there is increased interest in research that identifies features of effective professional learning" (p. 2).

In this context, the question of sustainability is of particular relevance. Despite its central importance for both, teachers and teacher educators, research on sustainable impact is generally lacking within teacher education disciplines (Datnow, 2006; Rogers, 2003). Hargreaves (2002) resumes: "As a result, many writers and reformers have begun to worry and write about not just how to effect snapshots of change at any particular point, but how to sustain them, keep them going, make them last. The

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sustainability of educational change has, in this sense, become one of the key priorities in the field” (p. 190). Similarly, Colbeck (2002) claims: “Despite its importance to the change process, institutionalization often receives little consideration by organizational participants” (p. 398). Van den Berg (2005) states that “most evaluations focus on short-term or intermediary results of the projects, programmes or policy to be evaluated” (p. 27).

However, a sound knowledge base concerning the issue of sustainability would be useful for understanding the long-term impact of teacher professional development programmes, in particular for mathematics teacher education. At the same time, this knowledge would allow thorough discussions regarding implications for upcoming professional development programmes’ planning, implementation, and evaluation. Although some research findings are available (see e.g., Zehetmeier, 2008, 2009) it would be important to enhance further research and evaluation to get new results regarding the sustainability of impact. Slavin (2004) complains: „Most innovations adopted on a large scale were never adequately evaluated in the first place ... but even among the small number that have been successfully evaluated, few have been able to maintain themselves in schools over an extended time period. Most often, innovations that have been enthusiastically adopted and even found to be effective in particular schools are later dropped, sometimes to be replaced by other innovations and sometimes for a return to the status quo ante” (p. 61).

In particular, the facilitators of professional development programmes can make use of expertise “to carry out the functions associated with the innovation, as well as with the strategic planning, in order to plan for sustainability. ... Knowledge of process and outcome evaluation methods is necessary to assess and understand the effectiveness of the innovation” (Johnson, Hays, Center, & Daley, 2004, p. 144). This is particularly relevant for teacher educators.

The aim of this article is to provide other disciplines’ knowledge concerning the sustainable impact of innovations and professional development programmes. For this, an extensive literature was carried out; using qualitative content analysis (Mayring, 2003), relevant topics were identified and clustered; this led to the following categories: the others’ rationale, the others’ definitions, the others’ theories, the others’ methods, the others’ factors, and the others’ discussions. After introducing “the others”, each of these categories is provided in the following sections. Then, implications for mathematics teacher education are discussed.

The others

Am I or are the others crazy?

(A. Einstein)

In this paper, the knowledge of other disciplines is provided to discuss some possible implications for mathematics teacher education. This leads to the question: Who are the others? Health care disciplines come with a relative long tradition of researching the topic of professional development’s sustainable impact. This led to a widespread body of research findings concerning this issue. Besides the health care disciplines also research on development aid or management research has available interesting findings; they also can be used as focal points for discussing and reflecting sustainability in mathematics teacher education.

Thus, this paper's literature review is based particularly on research findings from health care disciplines (e.g., Scheirer, 2005). Moreover, results from disciplines like development aid (e.g., van den Berg, 2006), management research (e.g., Lawrence, Winn, & Jennings, 2001) or public service evaluation (e.g., Savaya, Elsworth, & Rogers, 2009) are provided.

The others' rationale

The journey of a thousand miles begins with a single step.

(Laotse)

Why do the others this kind of research? This section provides some rationale, why the other disciplines invest time, money and other resources to research the question of sustainable impact of innovations and professional development programmes.

One reason is the improvement of a rather limited knowledge base: While there is rather sound knowledge regarding professional development programmes' implementation or evaluation, the knowledge of programme sustainability "tends to be contradictory and fragmented" (Pluye, Potvin, & Denis, 2004, p. 121). Programme planners, participants, or funders consider this issue to be highly important; but – when going into details – there are rather contradictory recommendations how to sustain a programme's impact over time. Pluye et al. (2004) state: "Little is known about the sustainability process. Consequently, it is difficult for public health practitioners to know how and when to influence the sustainability of 'their' programs" (p. 121).

This limited knowledge base may be due to the fact that "institutionalization² is typically assessed superficially, if at all" (Colbeck, 1999, p. 13c1-1). The reason for this lack of research seems to be "that impact assessments, ... five or more years after a project or activity has ended, are not easy to undertake, and consequently are not widely undertaken nor widely read" (van den Berg, 2005, p. 27). This includes particularly the claim that "impact assessments ... are too costly" (ibid., p. 28): The long-term time horizon makes this kind of research face "historical challenges ... if a very wide scope is chosen and historical reconstruction is part of the research. This often requires extended file and dossier research and analysis of historical data" (ibid.).

Another reason for researching the sustainability of programmes is its inherent importance for the programmes' success. Since "many programmes aim at behavioral changes, they must survive over an extended period of time for such changes to occur" (Pluye, Potvin, Denis, & Pelletier, 2004b, p. 489). Moreover, "there is often a latent period ... between when programs begin and when their effects on population ... are felt" (ibid.).

In this regard, one may discuss the question: What if sustainability of professional development programmes is not considered or achieved? Discontinued programmes bear the potential of bringing disillusion to participants and therefore posing obstacles to subsequent mobilization: "The absence

² Colbeck (2002) uses the term institutionalization to refer to sustainable impact; see also section "the others' definitions".

of sustainability would lead to an investment loss for the organizations and people involved” (Pluye et al., 2004, p. 122). Moreover, as van den Berg (2005) claims, if programme evaluation is limited to the study of input, output and the process in between, it can be used as a monitoring tool, but has rather limited value at the impact level: “... Monitoring will tell whether you are doing things right, but not whether you are doing the right thing. Evaluation can, if applied properly, answer the second question. Yet, if evaluation cannot or will not assess impact, or longterm results, will it be able to fulfil this promise?” (p. 28).

Given this range of rationale, a rather typical research question is for example: “What happens after the initial funding for new programs expires? Do the programs continue or end their activities or even expand to new sites or new beneficiaries?” (Scheirer, 2005, p. 320).

The others’ definitions

To define a thing is to substitute the definition for the thing itself.
(G. Braque)

How do the others define sustainability? This section provides an overview concerning the other disciplines’ definitions and conceptualizations of the notion “sustainability”.

One of the most basic definitions determines sustainability as maintaining programmes’ effects over a long period of time (Pluye et al., 2004b). This reflects the World Health Organization’s perspective which defines sustainability as “the ability of a project to continue to function effectively for the foreseeable future” (quoted in Amazigo et al., 2007, p. 2071). Similarly, Blasinsky, Goldman, and Unützer (2006) define sustainability “as the continuation of all or part of the program after initial external funding ends (p. 719). Savaya et al. (2009) provide a somewhat more differentiated definition: They apply the notion of sustainability to “both the preservation of program outcomes and the continuation of the program itself” (p. 2).

Some definitions are rather sophisticated and use degree or category models to define the notion of sustainability:

Pluye et al. (2004b) suggest four degrees of programme sustainability: (1) The absence of sustainability; (2) Precarious sustainability; (3) Weak sustainability; and (4) Sustainability through routinization (p. 489). The first degree refers to programmes with no on-going activity. The second denotes sustained programmes, whose future status is uncertain due to actors who “maintain some residual activities on an informal basis as part of their functions in the organization, but this is completely unrelated to the program. The continuation of these activities depends entirely on the initiative of these actors” (ibid.). The third degree refers to programmes, whose sustained activities are weakly maintained: “These activities may be subject to radical changes in the short term” (ibid.). Yet the fourth degree denotes sustained programmes with routinized results.

Sustainability as a question of routinization is already discussed by Yin (1979), who states: “When an innovation has become a stable and regular part of organizational procedures and behavior, it is defined as having become routinized” (p. 55). Similarly, Scheirer (2005) defines “sustainability as the institutionalization or routinization of programs into ongoing organizational systems” (p. 325). So programme activities can be most likely sustained “if the program components become embedded into organizational processes” (ibid.).

Shediak-Rizkallah and Bone (1998; quoted in Johnson et al., 2004, p. 137) use three categories to address the notion of sustainability: (a) maintaining benefits achieved through an initial program, (b) continuing the program within an organization, and (c) building the capacity of the recipient community to continue a program. The first of these categories refers to the basic definition of sustainability (see above). The second category concerns the continuation of programme activities within an organization and corresponds to Pluye et al.'s (2004b) fourth degree "sustainability through routinization" (see above). The third category goes beyond this routinization degree and refers to the continued capacity of a community to develop and deliver innovative programmes. This is also reflected by Johnson et al. (2004), who state: "The system must be receptive to change, thus creating an environment for innovations to adapt to the system, if necessary, to which they are introduced" (p. 137).

There is a number of varied notions in literature that address the issue of sustainability. Johnson et al. (2004, p. 136) list eleven of these terms: confirmation, continuation, durability, incorporation, institutionalization, level of use, maintenance, routinization, stabilization, sustainability, and sustained use. Another literature review by Pluye et al. (2004, p. 121) provides even more notions: adoption, appropriation, colonization, consolidation, durability, embedding, incorporation, integration, longevity, maintenance, nesting, permanence, perpetuation, persistence, routinization, survival, and viability. These and other authors (e.g., Savaya et al., 2009) claim that the most common notion with similar meaning is institutionalization.

Of course, all these notions are not used and conceptualized overall synonymously: different authors use different notions and hold different meanings on them. For example, Johnson et al. (2004) provide a clear distinction between sustainability and institutionalization: "Continued ability of an innovation (infrastructure or program) to meet the needs of its stakeholders is central to the sustainability process. ... In contrast, institutionalization refers to the long-term viability and integration of a new program within an organization. ... Thus, 'meeting the continual needs of stakeholders' vs. 'integration into business as usual' is one major distinction between the two terms" (p. 136). Yet another example for differentiated use of notions is provided by Pluye et al. (2004): They distinguish routinization and standardization. On the one hand: "Routinization constitutes the primary process permitting the sustainability of programs within organizations and may lead to program-related organizational routines. Memory, adaptation, values, and rules define organizational routines" (p. 124). On the other hand: "Standardization constitutes the secondary process permitting the sustainability of programs. This process is superimposed upon the primary process of routinization and may lead to program-related standardized routines that are more sustainable than simple organizational routines. Institutional standards introduce a higher degree of program sustainability" (p. 125).

Another aspect concerning the definition of sustainability is raised by Rogers (2003): He claims that an analysis of sustainable impact should not be limited to effects that were planned at the beginning of the programme; it is also important to examine unintended effects and unanticipated consequences that were not known at the beginning of the programme.

The others' theoretical models

Your theory is crazy, but it's not crazy enough to be true.

(N. Bohr)

How do the others frame the issue of sustainability theoretically? The following section provides an overview regarding the other disciplines' theoretical frameworks modelling innovative programmes' sustainability.

As a result of an extensive literature review, Pluye et al. (2004) state that "the development of programs is often modelled as a linear sequence of phases. The label of these phases may change but the sequence is typically one where planning, implementation, evaluation and sustainability phases follow one another chronologically with minimal overlap. The sustained program is the culmination of this 'stage' model" (p. 126). This statement is supported by an illustrative overview, which provides the various stages used by the respective authors (see Figure 1; *ibid.*):

Table 2

Illustration of the 'stage' model: empirical studies on health promotion

References of studies	List of phases
Barab et al. (1998)	Adoption Implementation Institutionalization
Bracht et al. (1994)	Design and initiation Implementation Evaluation Program maintenance
Butterfoss et al. (1998)	Formation of the coalition Implementation Maintenance Outcome and institutionalization
Goodman and Steckler (1989) ^a	Unsatisfied demands, search for response Evaluation of alternatives Adoption Initiation of action Implementation Institutionalization
Goodman et al. (1993)	Community mobilization Development of interventions Process outcomes Institutionalization
Goodson et al. (2001)	Program development Adoption Implementation Evaluation Institutionalization
O'Loughlin et al. (1998)	Awareness of the program Adoption Implementation (incorporation if needed) Institutionalization
Paine-Andrews et al. (1996)	Pre-planning Planning Implementation Institutionalization

Figure 1

Yet another kind of stage model is provided by Savaya et al. (2004), who distinguish different forms of possible programme continuation: A programme can be continued "(a) with similar activities and target groups, (b) with similar activities and new target groups, (c) with similar activities in a different location or community, and (d) with new activities and the same target groups, building on the previous work" (p. 4).

Although stage models are commonly used by various researchers (see Figure above), they are also critically discussed: A “stage model is deceptive in theory and artificial in practice. It suggests that a sustainability phase naturally follows a successful implementation phase. ... This model does not take account of the recursive or reflexive character of sustainability and learning or of the continuous adjustments that shape the sustainability process” (Pluye et al., 2004, p. 126). Moreover, within stage models it is rather unclear when and how sustainability can be fostered or assessed: “In a ‘stage’ model, what is sustained, in theory, prolongs what had been implemented. Thus, sustaining a program consists in finding the means of reinforcing, and making last what had been implemented” (ibid.). Following these considerations, Pluye et al. (2004) propose that programme implementation and programme sustainability are rather concomitant processes than successive phases: “Certain specific events influence sustainability, and others, implementation. Others influence both implementation and sustainability” (p. 127).

Rogers (2003) carried out an extensive review of literature concerning the diffusion of innovations. He proposes that innovations are adopted within social systems through a five-step process, taken by each of the system’s individuals: knowledge, persuasion, decision, implementation, and confirmation. In the first step, an individual knows the innovation on a rather superficial level. In the second step, the individual tries to get more information concerning the innovation. In the third step, a decision is made whether or not to adopt the innovation. Then, in the fourth step, the individual implements the innovation within the social system and evaluates whether it is useful. In the last step, the individual feels certain that the adoption and continued use of the innovation is a proper decision. Moreover, Rogers (2003) describes how innovations are adopted by particular typical groups of a social system: They start from innovators (about 3% of the social group’s members) and spread from a small group of early adopters (about 13%) over an early majority (another 34%) and the late majority (another 34%) to the laggards (about 16%) of the social system.

The others’ research methods

Take a method and try it. If it fails, admit it frankly, and try another. But by all means, try something.
(F. Roosevelt)

How do the others carry out research? The following section deals with the other disciplines’ research methods for analysing the sustainability of their programmes’ impact.

In general, there is no agreed-on method for how and when to evaluate sustainability: “Research on the general topic of ‘what happens after the funding ends’ for a specific program is not yet well conceptualized. ... Various authors tend to approach the topic in very diverse ways” (Scheirer, 2005, p. 323). Pluye et al. (2004) complain this issue: “it is difficult ... for researchers to study” (p. 121).

However, some theoretical frameworks which conceptualize routinization or institutionalization as central aspects of sustainability (see the others’ definitions, above) suggest “that studying sustainability requires searching for the presence of organizational routines or institutional standards” (Pluye et al., 2004, p. 125). Within some other frameworks which define sustainability as one (and mostly final) of various stages, the issue of sustainability “requires its own evaluation, apart from and usually after, an evaluation has shown positive results for the program intervention itself” (Scheirer, 2005, p. 344).

A common suggestion to enhance the validity of research results is using methods of triangulation: "Studies of sustainability should make greater use of methods to reduce potential bias in findings, such as contacting multiple respondents to obtain convergence in reports of organizational processes and using multiple sources of evidence" (Scheirer, 2005, p. 344).

Regarding sustainability's time horizon, some studies assess sustainability on the basis of participants' or leaders' projections immediately at the end of a programme. For example, Savaya et al. (2009) state: "At this point, the project leaders presumably had sufficient information to know whether their projects would be continued and in what form" (p. 5). Some other studies use qualitative research methods to document sustainability a certain time span after the programme's termination. For example, Blasinsky et al. (2006) gathered data (documents, observations, and interviews) approximately one year following the end of a particular programme.

The others' fostering factors

Form and function are a unity, two sides of one coin. In order to enhance function, appropriate form must exist or be created.
(I. Rolf)

Which factors promote the sustainability of the others' programmes? The following section provides other disciplines' research findings regarding factors fostering the sustainability of innovations or professional development programmes.

Literature regarding conceptual or empirical knowledge of factors that may foster the sustainability of innovations is rather sparse (Johnson et al., 2004). However, "the question of what factors contribute to or detract from program sustainability is important because ... it cannot be assumed that proven success in achieving its goals ensures a program's continuation beyond its initial funding" (Savaya et al., 2009, p. 2). The question which factors help increase the likelihood of sustainability is particularly addressed in literature regarding the institutionalization of programmes within organizations: "This issue is of central importance when one is planning for program sustainability, when it is helpful to know what processes and other influences need to be considered to extend the delivery of program activities" (Scheirer, 2005, p. 324).

This paper uses a qualitative analysis of literature (Mayring, 2003): Eight central factors, which foster the sustainability of programmes, were categorized. The following factors are central, because they were found to be influential more often than other ones: perceived benefit, innovation champions, mutual fitting, institutional support, sufficient resources, networking, ownership, and integration of rules. The following paragraphs provide an overview concerning these central factors.

Perceived benefit

One of the central factors fostering the sustainability of programmes is "the perceived benefit from the programme" (Amazigo et al., 2007, p. 2080) for the people involved. This implies in particular that "attention to the needs, attitudes, and perceptions of adopters is critical to their sustained use of an innovation" (Johnson et al., 2004, p. 143). And further: "Users must perceive a benefit to the innovation beyond that of current practices. ... Adopters are also more likely to sustain an innovation

if they believe it is effective" (ibid. p. 145). Baum et al. (2006) state that some "initiatives were often only felt to have happened because of the previous collaborations. ... In effect these had laid the seed bed on which future projects grew" (p. 262).

In particular, the "evidence that the model works ... and the ability to document positive client outcomes" (Blasinsky et al., 2006, p. 721) represents a strong fostering factor. On the other hand, Scheirer (2005) highlights that these "benefits to staff members and/or clients ... are readily perceived, but not necessarily documented via formal evaluation" (p. 339).

Pluye, Potvin, Denis, Pelletier, and Mannoni (2005) found incentives to be a factor fostering the sustainability of innovations: "The promotion of personnel (into positions of greater responsibility and power) encouraged the routinization of innovations. ... Adding concrete benefits to human resources also constitutes an incentive (for example, in the form of convenience or reduced effort)" (p. 125).

Innovation champions

Another central factor that supports the sustainability of programmes is "the presence of champions for an innovation" (Johnson et al., 2004, p. 138). Similarly, Scheirer (2005) highlights "the key role of a program champion" (p. 339). Also Savaya et al. (2009) state that "program champions who promote the program in the organization and the community can contribute to program sustainability" (p. 2).

These champions are "formal and informal leaders within adopting systems ... who proactively promote an innovation from inside or outside of a system" (Johnson et al., 2004, p. 143). They "are critical to creating an environment that supports and facilitates sustaining innovations. ... Such champions can serve as brokers on behalf of the innovation with other decisionmakers" (ibid.). Johnson et al. (2004) describe in detail: "Essential skills for innovation champions include communicating their commitment to the innovation, ... engaging others, overcoming barriers, building infrastructure, thinking and learning reflectively, summarizing and communicating, coaching for sustainability, and building further organizational capacity to spread the innovation" (p. 144).

Blasinsky et al. (2006) point to the importance of staff members who are "already trained [in the programme]" and are "available not only to continue [the programme] but also to train others in the intervention" (p. 726).

Mutual fitting

Yet another central factor fostering sustainability is the fitting of innovations and adopting institutions. For example, "when program objectives fit with the values of the organization and staff" (Pluye et al., 2005, p. 125). Or "when cultural artifacts from program activities are shared with organizational artifacts" (ibid.); here, artifacts are defined as myths, symbols, metaphors and rituals that express a set of organizational values, beliefs and feelings. Another kind of fitting is represented by "the adaptation of activities according to their context or environment" (ibid.); in this case, adaptation means the adjustment of activities regarding local contexts and environmental variations. In sum, this refers to introducing innovations into organisations without "disruption of the operating work flow" (p. 126).

Johnson et al. (2004) state that sustainability is fostered when innovative programmes are “compatible with the philosophical orientation ... and internal agenda of users” (p. 145). Similarly, Scheirer (2005) claims for “a substantial fit with the underlying organization’s mission and procedures” (p. 339). This challenges both the organisations’ stability and flexibility: “The stability of an organization and its ability to change significantly contribute to the sustainability of new programs” (Savaya et al., 2009, p. 2).

Institutional support

Institutional support is another central factor that supports the sustainability of programmes. This can be mirrored by the “willingness of the organization to promote change” (Blasinsky et al., 2006, p. 726). Or when organisations take the risk of supporting innovative programme activities: Because then organisations “build confidence among actors involved in activities and encourage the routinization of programs” (Pluye et al., 2005, p. 124).

For this, the administration of organisations “must have the structures and capacity necessary to carry out administrative functions related to an innovation responsively, effectively, and efficiently” (Johnson et al., 2004, p. 144). In this regard, it is important to know that “systems that focus on strengthening administrative capacity to support an innovation during its initial implementation are more successful at sustaining the innovation once the initial trial ends” (ibid.).

Sufficient resources

Yet another central factor fostering sustainability is the availability of resources. Johnson et al. (2004) state that “sustainability research clearly identifies resources as important to sustaining innovations” (p. 143). These resources include human, physical, technological, financial and informational resources (Pluye et al., 2005; Johnson et al., 2004). Sufficient resources can support the sustainability of programmes in the case of “equipment turnover (renewal of material resources when needed)” or of “turnover in key personnel (change of original personnel after an appropriate period of time)” (Pluye et al., 2005, p. 124). To ensure the availability of sufficient resources, programmes can “have multiple sources of funding”, and/or “the project leaders can plan to raise resources for the future, when fund raising starts early on” (Savaya et al., 2009, p. 2).

Networking

Savaya et al. (2009) highlight the importance of networking: “Self-contained programs are less likely to be sustained than are programs that are well integrated with existing systems” (p. 2). In this regard, Pluye et al. (2005) state “that transparent communication between the actors is necessary to achieve congruence among objectives, to share cultural artifacts, and to take corrective actions, thus promoting routinization” (p. 125). For networking, some “positive relationships among key implementers” (Johnson et al., 2004, p. 138) are useful: “Collaboration between program developers and teachers who are implementing the program appeared to increase their commitment and desire to implement the new procedures. A supportive peer network among implementers of an innovation is also important for sustaining innovations” (ibid.).

Ownership

Savaya et al. (2009) point to the factor ownership as being central for sustainability: They found “greater sustainability of programs that were developed and implemented with the involvement and support of community bodies” (p. 2). Also Johnson et al. (2004) indicate the importance of “ownership by ... system stakeholders” (p. 138) as factor fostering the sustainability of innovative programmes. Similarly, Amazigo et al. (2007) point to the fostering influence of “community leaders [who] show appreciation” (p. 2080) for the programmes.

Integration of rules

Research findings of Johnson et al. (2004) suggest that the integration of rules is another fostering factor: “Policies and procedures ... assure that the innovation remains part of the routine practice of the organization, even after the top management who advocated sustaining the innovation leaves the organization. (p. 143). For Yin (1981), sustainability is fostered when “program functions become part of job descriptions and prerequisites” or when “the use of innovation becomes part of statute, regulation, manual, etc.” (p. 63).

The others’ hindering factors

Avoid problems, and you'll never be the one who overcame them.
(R. Bach)

Which factors hinder the sustainability of the others’ programmes? The previous section provided an overview regarding the other disciplines’ fostering factors. Of course, one can consider the non-occurrence of a fostering factor as a hindering factor per se. The following section goes beyond this consideration and provides the others’ findings dealing explicitly with factors hindering the sustainability of programmes or innovations.

One major hindering factor is staff turnover: “If there is turnover of the initial program director or champion, and the implementing organization does not continue the training and support after the initial implementers leave” (Scheirer, 2005, p. 340). Similarly, Slavin (2004) states: “Innovations are often brought in or championed by ... a small number of staff members, and a program may disappear when these people move on” (p. 61).

Another factor that hampers sustainable impact of innovations or programmes is represented by organizational or structural barriers. Blasinsky et al. (2006) state that “the inability or resistance of health care organizations to change their systems of care” (p. 725) is a crucial obstacle.

Financial issues represent yet another hindering factor. For example, Blasinsky et al. (2006) claim that “despite the fact that the program model worked well, ... it was not possible to overcome the barriers of funding issues” (p. 725). In some cases, it is not the mere amount of money that influences sustainability: Slavin (2004) found that “even programs that do not cost much may still disappear when funds are cut, as [people involved] cut back on professional development or materials budgets, or simply become demoralized” (p. 61).

Pluye et al. (2005) point to the recognition of failure as a hampering factor: “Failed or ineffective activities, when recognized, hinder routinization. ... Failure to deliver activities hampers the ends of routinization, because the organization then reinforces its traditional activities, which are considered sure to succeed” (p. 125).

The others' discussion

*A scientist's aim in a discussion with his colleagues is not to persuade, but to clarify.
(L. Szilard)*

How do the others discuss their research findings? In this section, some exemplary lines of discussion are provided.

In general, the research findings are not convergent or clear-cut: "Research on the topic of program sustainability, although greatly needed, is not likely to develop and validate a single set of guidance about 'how to do it'. ... It is likely to remain multifaceted, with results contingent on the specific programs and contexts in which they are operating" (Scheirer, 2005, p. 325).

Some results are "are counterintuitive and inconsistent with the literature" (Savaya et al., 2009, p. 13) and point to rather paradox situations: "It may be conjectured that the more effective a project is, the less needed it seems to be and the less reason there seems to be to continue it. Conversely, less effective projects may give rise to the expectation that efforts will be made to persevere until they attain their aims" (ibid.).

The other disciplines discuss the question of how and when integration of sustainability issues in programme planning is reasonable and necessary: "Decision-makers involved in implementing an innovation must face the ultimate challenge of planning for the time when the implementation phase is completed" (Johnson et al., 2004, p. 136). But when should this planning take place? Pluye et al. (2005) suggest: "The planning of sustainability begins at the very start of programs. This reflexive approach departs from the recommendations suggested by the stage model ... in which sustainability is only considered after programs are implemented" (p. 135). Similarly, Scheirer (2005) postulates early planning and formative evaluation of programme sustainability: "The timing of evaluation findings is often too late in the project life cycle to be useful in promoting sustainability; evaluation could be more useful if it included continuously accumulated data about major outcomes, so that interim data about outcomes would be available before the initial funding ends" (p. 344).

The other disciplines clearly note that sustainability is not a value per se. In some cases, it is not only non-essential, but rather not desirable or worthwhile: "Not all innovations need to be continued because circumstances, people, situations, and problems change. ... Further, an effectiveness evaluation may find that an innovation does not work outside of specific controlled conditions" (Johnson et al., 2004, p. 136). It is recommended that "a sustainable innovation should be proven to be of benefit to the diverse stakeholders (users of the innovation) prior to adoption" (ibid., p. 138).

Yet another discussion line is of epistemological nature: If research provides results, how can we know that we got it right? This is a question of validity. Van den Berg (2005) discusses the question of causal linkages between programme and sustainable impact: "By definition these linkages grow weak beyond the immediate reach of the activities and become more hypothetical in nature. ... But if attribution is reduced to the idea that the outcomes are 'just one of many factors contributing to a certain impact', then we might ask: is it all worthwhile? Should we spend a lot of money on an evaluation that will not establish attributable impact?" (p. 29).

Another rather general obstacle for sustainability is discussed by Pluye et al. (2004): “Traditionally, institutions are stable, and institutional changes are rare and come about in a radical manner after the mobilization of the population or after hierarchical, authoritarian decisions” (p. 125).

Facing forward, the others plea for further research on the issue of innovations’ and programmes’ sustainability: “It is strongly needed to consolidate empirical evidence and to test strategies aimed at increasing the numbers of sustained programs” (Scheirer, 2005, p. 325). And: “Funders should continue to provide support for evaluation to go beyond the usual focus on ascertaining effectiveness to grapple with these longer term issues of sustainability” (ibid, p. 342).

Discussion and implications

*Always desire to learn something useful.
(Sophocles)*

This section links the others’ respective categories (rationales, definitions, theories, methods, factors, and discussions) to mathematics teacher education. Communalities can indicate possible affirmations and validations of our discipline’s knowledge. Differences may point to aspects worth being challenged and reconsidered. In the following, each category is discussed and possible implications are suggested.

Discussion and implications of rationales

The other disciplines state that knowledge about sustainability is rather contradictory (see the others’ rationales above); however, teacher education’s knowledge base is too scarce to be compared and judged as convergent or inconsistent. Therefore, further research on this issue is strongly recommended, from the perspective of both scholarship and practice.

An obstacle indicated by the others is that “Impact assessments ... are too costly” (see above). Similar arguments are hindering research in the mathematics teacher education domain: In most cases, after the end of a particular programme, the funders’ focus (and funding) shifts to new projects; time and money are invested in a new project, which limits or terminates the financial and administrative possibilities of the previous programme: “Reformers and reform advocates, policymakers and funders often pay little attention to the problem and requirements of sustaining a reform, when they move their attention to new implementation sites or end active involvement with the project” (McLaughlin & Mitra, 2001, p. 303). However, from a financial perspective, it would make sense to analyse the long-term and sustainable effects: “Too many resources are invested in professional development to ignore its impact over time” (Loucks-Horsley et al., 1996, p. 5). Therefore, the classical financial argument (against the research of sustainability) should be objected and not be any more left without contradiction.

The research questions of the other and the teacher education disciplines are often similar or the same. Therefore, the respective research projects may be highly interesting for each other and should be received accordingly.

Discussion and implications of definitions

The other disciplines are using degree or category models to conceptualize sustainability (see the others' definitions above). The teacher education disciplines use similar models, for example a stage model called "hierarchy of sustainability" (Seufert & Euler, 2004): At stage 1 an innovation is sustained due to a social group's own interest, to obtain the material benefits of the programme. Seufert and Euler (2004) call this level project-oriented sustainability and emphasize that this level implies the risk of isolated island solutions due to a lack of development perspectives. At stage 2, an innovation is maintained not only by those directly involved, but leads to an efficiency increase of the entire system. Fullan (2006) refers to this as lateral capacity building; Seufert and Euler (2004) call this level system-oriented sustainability. While expanding the perspective beyond the immediate programme boundaries, however, this level "neglects the emergence of a future-oriented problem-solving potential to increase the performance and innovation capability of the organization" (Seufert & Euler, 2004, p. 10). At stage 3, the innovation leads to behavioral changes which allow the involved individuals or organizations to respond flexibly and appropriately to environmental conditions. Thus innovations implemented during the programme can be adapted accordingly. Seufert and Euler (2004) refer to this as potential-oriented sustainability.

Two components of sustainability can be distinguished: On the one hand, sustainability refers to structures, rules, knowledge, attitudes or practices; thus the resources and potentials, which were created during the programme period. On the other hand and in addition to this structural component, the functions of these potentials are in the focus, when the programme and the associated external support come to an end. The issue here is not primarily about problem-solving, but rather about the development of a problem-solving capacity. In this regard, Fullan (2006) states: "Sustainability requires continuous improvement, adaptation and collective problem solving in the face of complex challenges that keep arising" (p. 119). In this context, sustainability means "changes in practice and deepening understanding in ways that keep vital practice, responsive to changes in students, subject area content and classroom contexts" (McLaughlin & Mitra, 2001, p. 304). This dynamic component is particularly reflected at stage 3 (see above). Therefore, it seems reasonable that professional development programmes should define and aim at enhancing this potential-oriented sustainability.

Given the various and diversified definitions of sustainability (see the others' definitions above), one can discuss which of the different conceptualisations should be particular goals of professional development programmes. For example, Scheirer (2005) claims that routinization has not necessarily to be an intended outcome of the life cycle of a programme. Moreover, she suggests instead that "capacity building and innovativeness generated by the development of new programs is the more important outcome that should be sustained" (p. 324). In the domain of teacher education disciplines, Hargreaves and Fink (2003) state: "Sustainability is more than a temporal matter" (p. 2). Similar to Scheirer (2005), they hold a differentiated perspective on the notion: "Sustainability does not simply mean whether something will last. It addresses how particular initiatives can be developed without compromising the development of others in the surrounding environment now and in the future" (Hargreaves & Fink, 2006, p. 30). This meaning of sustainability causes various effects: Firstly, it means promoting more broad-based programmes with benefit for many people and organizations, rather than encouraging short-term and small-bounded programmes: "Sustainable improvement demands committed relationships, not fleeting infatuations" (Hargreaves & Fink, 2003,

p. 3). This means in particular to aim at impact that enables people to promote innovations and change independently: "Sustainable improvement requires investment in building long term capacity for improvement, such as the development of teachers' skills, which will stay with them forever, long after the project money has gone" (ibid). Similarly, Fullan (2006) defines sustainability in the regard of educational change as "the capacity of a system to engage in the complexities of continuous improvement consistent with deep values of human purpose" (S. 114). In sum, the potential for self-renewal is the focus: Sustainability means that people and institutions react autonomously to changing conditions; they generate and apply new processes and products according the respective new conditions. At least, the great number of definitions and conceptualizations shows the interest of research and practice in this topic: "This profusion of terminology is testament to the significant desire for better comprehension of the phenomenon" (Pluye et al., 2004, p. 121). Therefore, projects researching the impact of innovations or professional development programmes should clearly reflect and consider which perspective and meaning of sustainability is informing the analysis.

Another aspect of the definition of sustainability is the time horizon. Most definitions have in common the continued focus on long-term impact. But at the same time it remains unclear how long "long-term" may be. It remains unclear whether sustainability is given after one month or after ten years of permanent continuation "There is no commonly accepted time point for defining when a program is sustained" (Scheirer, 2005, p. 334). When is it reasonable to call some changes sustainable? "At times, the time horizon of sustainability is so broad (in extreme cases indefinite), that evaluation of sustainability is administratively impossible" (Stockmann, 1993, p. 27). Therefore, each examination of lasting impact necessarily has to define what time period is encompassed by the term sustainability.

Whereas some innovations are adopted rather quickly, some other change processes need more time to be carried out. The reasons for this are manifold. For example, "there might be a tendency to keep staff members on the payroll for a time, to maintain only some activities of a broader initiative, or to keep a recent initiative going for political or face-saving reasons, even if it is not sustained permanently" (Scheirer, 2005, p. 334). Therefore, each innovation that aims to be sustained has to carefully reflect this issue.

The occurrence and analysis of not intended impacts (besides the intended ones) is not very common in the other disciplines (see above). Similarly, the teacher education disciplines do not distinguish intended or not intended, expected or not expected impact within their definitions of sustainability (Zehetmeier, 2008). An impact analysis that only evaluates intended and expected effects remains incomplete in the sense of a nominal-actual value comparison. Therefore, sustainability definition and research need to take systematically into account the unintended and unexpected impacts.

Discussion and implications of theories

The other disciplines use various theoretical frameworks to model the sustainability of impact (see the others' theories above). When analysing teachers' professional development, the question of possible levels of impact is important. Many papers which deal with teachers' professional development put teachers' learning in the main focus (see e.g., Guskey, 2000; Lipowsky, 2004, 2010; Sowder, 2007; Zehetmeier, 2008). The major categories for describing teachers' learning are their beliefs, knowledge, and practice (Zehetmeier, 2011). The IPD model (Impact of Professional

Development model; Zehetmeier, 2009) comprises a rather wide range of possible levels of impact: The categories knowledge, beliefs, and practice are used to analyse the impact on the teachers' level as well as on other in-school and beyond-school levels. Within this model, the core elements that constitute professional development activities are the teachers, the facilitators, the programme itself, and the context which embeds the former three (Borko, 2004). The IPD model also provides the mediating factors that foster the professional development programme's impact.

Figure 2: The IPD-model

Knowing the theoretical frameworks may help researchers and practitioners to better understand an innovation or programme becoming sustainable (or not). Therefore, it seems reasonable for both, scholarship and practice to know possible frameworks and to make use of them. For example, the knowledge about the existence of innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003; see the others' theories above) as types of adopters, can help to effectively cooperate with the respective types.

While the IPD model is well suited as a tool to describe the impact of professional development programmes, it remains open, how to explain and theoretically frame causal linkages. The question arises, whether the described impact is really due to the particular professional development programme, or due to some other sources (which may be the case). Van den Berg (2005) discusses this issue: "The question of causality is central to establishing impact. The model that evaluations have used in this regard is that of causal linkage, allowing for attribution of observed changes to the intervention" (p. 30). However, this emphasis on causal linkages may lead to the (public) opinion "if no causal linkage can be established, perhaps we should stop it". Thus, van den Berg (2005) suggests to carefully analysing what casual linkage may mean: The common concept of cause is grounded in physics, where a causal relationship refers to a linkage that has been established both theoretically and empirically. However, teacher education cannot refer to causality as something that is established through existing scientific theories, since there are too many activities and circumstances for any general causality to be established: "We seem to lack general causality and we need to restrict ourselves to specific causality" (ibid., p. 31). Van den Berg (2005) states further that there is one exemplary field of expertise particularly interested in describing the multitude of specific events and that is history: "Historians are thus interested in the circumstances and events that caused other events to take place as they did. ... Many evaluations tend to be historical in nature ... in the sense that they describe what happened and why, rather than carrying out systematic scientific assessments of the linkages between interventions and changes in society" (p. 32).

In sum, there is a wide variety of meanings of the notions causality and linkage. If research on programmes' sustainability uses a rigorous approach which considers many factors contributing to impact, then therefore the term contribution should be preferred (rather than causal linkage). In this regard, van den Berg (2005) proposes that research "should move from the concept of linear causality to the concepts of conditionalities (necessary but not sufficient conditions for changes to occur). Furthermore, it should be made clear that these necessary but not sufficient conditions contribute to rather than cause the change to take place" (p. 34).

Discussion and implications of methods

The methods used by the other disciplines do not have any gold standard method to research the sustainability of programmes. Within the teacher education disciplines the tradition and experience with this kind of research are rather limited (Datnow, 2006); thus there is no standardised agreed-on method. Many research projects (e.g., Zehetmeier & Krainer, 2011) follow a case study design (Yin, 2003), since this approach seems particularly suited for analysing the impact of innovations: "The usual survey research methods are less appropriate for the investigation of innovation consequences. [...] Case study approaches are more appropriate" (Rogers, 2003, p. 409). Similarly, Hancock and Algozzine (2006) state: "Through case studies, researchers hope to gain in-depth understanding of situations and meaning for those involved" (p. 11). This implies the use of methods of triangulation, which is common in both the other and teacher education disciplines. Triangulation comprises data from various sources and time periods to gain validity by "convergence of evidence" (Yin, 2003, p. 100). Similarly, Scheirer (2005) recommends: "Researchers publishing articles about sustainability should be sure to fully document their methods for data collection and analysis, so that the likely validity of their findings can be assessed in relation to the methods used in each study" (Scheirer, 2005, p. 344). Therefore, the use of qualitative research methods, in particular of case studies with triangulated data, seems a reasonable method for analysing the sustainable impact. This does not mean to exclude quantitative data; rather it suggests combining qualitative and quantitative data within a mixed methods setting. This can lead to differentiated evidence from various perspectives: Quantitative surveys' results provide an overview, and qualitative analyses' findings lead to a mosaic of particular cases. Both the overview and the mosaic together can help to better understand the sustainable impact of teacher professional development programmes (Zehetmeier, 2011).

Discussion and implications of factors

The other disciplines identified several factors that foster or hinder the sustainability of programmes (see the others' factors above). In a meta-analysis concerning factors in the teacher education disciplines, Zehetmeier (2008) found yet similar, but not the same factors. For example, mutual fitting, ownership, and networking turned out to be central fostering factors in both the others' and teacher education literature. Therefore, it seems reasonable to facilitate factors identified by both domains.

Zehetmeier and Krainer (2011) highlight in particular the outstanding relevance of contextual factors. Similarly, a study of Nickerson and Moriarty (2005) points to organizational conditions (e.g., teachers' relationships with the school administration) being highly relevant for the further development of schools. Since contextual factors contribute particularly to sustainable impact, organisational

development should be part of any professional development programme. This means, that not only mathematics teachers should be seen as a programme's target group, but also the teachers' contexts (e.g., colleagues, pupils, principals, parents, policies, etc...). Therefore, professional development and school development should be considered as concomitant processes.

Rogers (2003) highlights that the diffusion of an innovation depends on different characteristics: Relative advantage, compatibility, complexity, trialability, and observability. Fullan (2001) describes similar characteristics (need, clarity, complexity, quality, and practicality) influencing the acceptance and impact of innovations. Relative Advantage includes the perceived advantage of the innovation (which is not necessarily the same as the objective one). Compatibility and need denote the degree to which the innovation is perceived by the adopters as consistent with their needs, values and experiences. Complexity and clarity include teachers' perception of how difficult the innovation is to be understood or used. Trialability denotes the opportunity of participating teachers to experiment and test the innovation (at least on a limited basis). Quality and practicality make an impact on the change process. Observability points to the claim that innovations should be visible to other stakeholders. Therefore, when aiming at sustainable impact, the following implications should be considered: An innovation with greater relative advantage will be adopted more rapidly. More complex innovations are adopted rather slowly, compared to less complicated ones. Innovations that can be tested in small steps represent less uncertainty and will be adopted as a whole more rapidly. High quality innovations that are easily applicable in practice are more rapidly accepted. Innovations which are visible to other persons and organisations are more likely to be rapidly accepted and adopted.

Shediac-Rizkallah and Bone (1998) categorized three groups of factors that foster or hamper programmes' sustainability: (a) factors pertaining to the project; (b) factors within the organizational setting, and (c) factors in the broader community environment. Zehetmeier and Krainer (2011) try to reduce the multiple factors' complexity by clustering them into three dimensions (the three Cs; see Krainer, 2006): Content (high level and balance of subject-related action and reflection), Community (high level and balance of individual and social activities, in particular fostering community-building within and outside the professional development programme), and Context (high level and balance of internal and external support). Thus, both domains acknowledge the rather complex system of factors and try to establish useful and suitable models. Therefore, if professional development programmes are aimed to be sustainable, it seems crucial to carefully consider and facilitate these fostering and hindering factors. If some of these factors are dependent from the programmes' existence, then these factors may be substituted with alternative ones that are less or not at all connected to the programmes' existence.

Leadership as fostering or hindering factor is not really a topic in the others' disciplines. Indeed, Johnson et al. (2004) point to "effective leadership" (p. 138) being a fostering factor. However, it remains unclear, what this notion may mean. By contrast, within the teacher education disciplines the issue of leadership is of great importance. The results of several studies suggest the central influence of school leadership to the (sustainable) impact of school innovation initiatives (e.g., Fullan, 2006; Owston, 2007): Fullan (2006) proposes a direct correlation between the sustainability of innovations and the new role of school leadership: "This new leadership, if enduring, large scale change

is desired, needs to go beyond the successes of increasing student achievement and move toward leading organizations to sustainability”(p. 113). These new leaders focus on systemic relationships to foster sustainability not only on the individual level, but also on the levels of organisations or educational systems. “Such leaders widen their sphere of engagement by interacting with other schools in a process we call lateral capacity building. When several leaders act this way they actually change the context in which they work” (ibid.). Fullan (2006) calls this new type of leadership “system thinkers in action” (“they have the capacity to be simultaneously on the dance floor and the balcony”, p. 114). Similarly, Owston (2007) states: “Support from the school principal is another essential factor that contributes to sustainability” (p. 70). He distinguishes three types of administrative support: Neutral leaders (who meet innovations rather passive without promoting or prohibiting); Supportive principals (who create and support beneficial environments for innovations); And actively involved leaders (who are driving visionary ideas, identify personally with innovations and motivate other teachers for the innovation). Therefore, for programmes aiming at sustainable impact, it seems indicated to foster and support this kind of leadership; particularly regarding related hindering factors like staff turnover or organizational barriers (see the others’ hindering factors, above), this issue becomes highly relevant.

Another felicitous sentence concerning the complexity of fostering and hindering factors is provided by Slavin (2004): “With the many ways that innovations can be undone, it is perhaps more surprising when they do maintain over time than when they do not” (p. 61). Therefore, each programme has to carefully consider its respective fostering factors regarding the sustainability of impact, since each professional development programme has its own and particular objectives, contents, methods, and environments. Considering these factors in the programme’s planning may help to establish sustainable impact.

Summary and outlook

The future influences the present just as much as the past.

F. Nietzsche

This paper is about the sustainability of professional development programmes. Therefore, it provides the knowledge of other disciplines to discuss possible implications for mathematics teacher education. A literature review reveals the others’ rationales, definitions, theories, methods, factors, and discussions. With regard to teacher professional development programmes the following implications can be deduced. The main recommendations for mathematics teacher education are:

Teachers, facilitators, and researchers of professional development programmes should

- during planning
 - plan for sustainability from the very start,
 - clearly reflect which meaning of sustainability is informing the activities,
 - know theoretical frameworks and to make use of them,
 - define what time period is encompassed by the term sustainability,
 - take systematically into account the unintended and unexpected impacts,

- during implementation
 - know and facilitate (or avoid) fostering (or hindering) factors,
 - consider professional development and school development as concomitant processes,
 - focus on factors that are less dependent from the programme's existence,
 - aim at potential-oriented sustainability,
 - foster and support sustainable leadership,
 - be prepared for staff turnover,
 - receive and use other disciplines' knowledge,
- during evaluation
 - reject the classical financial arguments against the research of sustainability,
 - gather data during, at the end, and some while after the programme,
 - combine qualitative and quantitative methods within a mixed methods setting,
 - use methods of triangulation,
 - aim for contributions rather than causal linkages,
 - promote further research on the issue of professional development programmes sustainable impact.

Programmes which consider and accept these recommendations are likely to produce a higher rate of sustainable impact.

When discussing and researching professional development programmes' sustainable impact, the fostering and hindering factors are playing the central role. Knowing and being sensible for them is prerequisite for any conceptualization, implementation and evaluation of future professional development programmes which aim at sustainable impact.

Thus, further, broader as well as deeper research of professional development programmes' sustainable impact and their respective fostering and hindering factors appears to be promising from both scientific and practical perspectives.

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