Implementing Problem Solving in Mathematics Classrooms: What Support do Teachers Want?

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Providing teachers with support for the implementation of problem-solving approaches in classrooms is critical if classroom practices are to change. Finding the most appropriate professional development program can be challenging given the constraints of time, cost and personnel. Involving teachers in decisions about their professional learning needs is crucial if they are to embrace such approaches. In this paper, primary and secondary school teachers' responses to surveys about the problem-solving professional development needs of their colleagues, are presented. In general, teachers agreed that considerable support was necessary, particularly in the form of time and resources so that teachers can share teaching ideas, reflect on practice, and develop new understandings about these approaches.

Teachers have been required to implement problem solving into the teaching and learning of mathematics for some time. Stacey and Groves (1989) noted that every Australian state and territory included problem solving as part of their curriculum aims by 1988. To support problem-solving approaches in classrooms, resource materials and professional development opportunities have been available for teachers. One notable example was the *Mathematics Curriculum and Teaching Program Professional Development Package* [MCTP] (Lovitt & Clarke, 1988). Although there has also been an increase in research on problem solving (Lester, 1994), the recent TIMSS Video study (Hollingsworth, 2003) into Year 8 mathematics classrooms suggested there was little evidence of teachers using challenging problems. Discussions with primary teachers and secondary mathematics teachers reveal general support for problem-solving approaches. Teachers agree that problem solving is important and that students need to develop a range of problem-solving skills (Anderson & White, 2004). So why is there little evidence of the use of challenging problems in Year 8 mathematics classrooms? What issues exist for teachers to explain the lack of implementation? What changes or support would teachers welcome? This paper explores these questions based on the responses of groups of practicing teachers to similar questions presented in surveys.

Implementing Problem Solving in Mathematic Classrooms

Evidence of Change

The call for reform in mathematics classrooms has expected teachers among other things "to create supportive learning environments, to utilise worthwhile mathematical tasks, to manage students' mathematical discourse, and to promote sense making" (Jones, 2004). In the curriculum documents of most Australian States, these aspects are incorporated into strands or themes, such as *Working Mathematically* in NSW (BoSNSW, 2002), which also include problem solving. According to Guskey's (2002) model of teacher change, if teachers have been provided with relevant professional development to support these reforms, and if they have responded to the advice by changing their practice, we would expect students to have improved problem-solving outcomes (Figure 1). So is the increased emphasis on learning about problem solving evident in student outcomes from international studies?

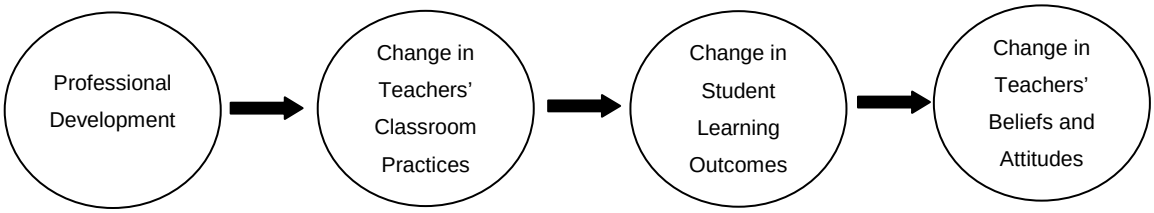

Figure 1. A model of teacher change (Guskey, 2002, p. 383).

The recently released results from the Programme for International Student Assessment [PISA] (Thomson, Cresswell & De Bortoli, 2004, p. xi) indicate that Australia's 15-year-old students are performing quite well compared to other countries since "in problem solving, more than 25 per cent of Australian students were performing at the highest proficiency level". However, 9 per cent were not achieving at the most basic problem-solving level. It should be noted, "the assessment of problem solving was designed to assess the degree to which students could solve problems situated in contexts that were discipline-free and drew on students' knowledge from a variety of sources" (p. 153). As such, these problems may not be typical of the problems solved in mathematics lessons.

In the Trends in International Mathematics and Science Study [TIMSS] 2002/3 (Thomson & Fleming, 2004), 5 per cent of Year 4 students reached the advanced international benchmark compared to 38 per cent in Singapore, while 7 per cent of Australian Year 8 students reached this benchmark compared to 44 per cent of Singapore students. The Year 8 advanced benchmark states that "students can organise information, make generalisations, solve non-routine problems, and draw and justify conclusions from data". Five per cent and seven per cent are rather small proportions of these two student populations who are able to work at this level.

Kaur (2001) explored the reasons for the success of Year 8 students from Singapore in both the Third International Mathematics and Science Studies [TIMSS] and TIMSS-R and noted the emphasis in the mathematics curriculum on "the development of mathematical concepts and skills, and the ability to apply them to solve problems" (p. 141). She reported that in lessons, teachers place a major emphasis on students solving non-routine problems. In contrast, research into teaching approaches in a random sample of 87 Year 8 classrooms in Australia suggests that few complex problem-solving opportunities are being provided (Hollingsworth, 2003). In her response to the TIMSS 1999 Video Study, Stacey (2003, p. 119) described the average Australian lesson as constituting "a syndrome of shallow teaching, where students are asked to follow procedures without reasons". It has been proposed that one factor that has influenced the lack of adoption of problem-solving approaches has been the teachers' knowledge and beliefs about mathematics teaching and learning (Stigler & Hiebert, 1999).

Providing Support for Teachers

Increasing the level of support for teachers through appropriate professional learning experiences is one strategy that may address the lack of adoption of problem-solving teaching approaches. It is noted that in Singapore, where teachers do place an emphasis on problem solving, they are entitled to 100 hours of in-service training each year (Kaur, 2001).

Professional development can take many forms that include conferences, workshops, regular collaborative meetings between groups of teachers, networking between schools, and school and university partnerships. Several Australasian studies have focussed on the

impact of professional partnerships between academics and teachers using the model of 'critical friend' to explore teachers' practices, and determine the level of implementation of problem-solving approaches. In her study of five primary school teachers, Smith (2000) investigated teachers' pedagogical practices and developed a teaching/learning framework for promoting thinking and understanding. Open-ended tasks provided the vehicle for thinking, reflecting and communicating mathematically. Keast (2003) has also described one primary school teacher's journey as she used more problem-solving approaches including open-ended tasks. The teacher's reflection and involvement in professional development opportunities seemed to provide a catalyst for the change.

Jaworski (1994) explored investigative teaching with a small group of teachers and developed a characterisation of this style of teaching which she called the "teaching triad". She defined investigative teaching as teaching which encouraged students to interact and work out things for themselves, with teachers importantly talking *with* and not at students. She also defined it as "a deep level of enquiry into the motivations and beliefs of the teachers concerned" (p. 204). Working closely with two teachers in each of three schools for approximately six months, provided a stimulating professional development opportunity for those involved. Ongoing, extended discussions with the teachers enhanced reflection and supported their development as investigative teachers.

Together these studies suggest that the support of an academic mentor is a productive strategy to assist teachers in implementing problem-solving or investigative approaches, but this needs to be explored on a larger scale if change is to be realised for more teachers. One way to design relevant and worthwhile professional learning opportunities for teachers is to seek advice about their needs.

What support do teachers want?

In an evaluation of a larger study of school structures and professional development that supported or impeded change in mathematics and science classrooms, Gamoran and his colleagues (NCISLA, 2002) identified several key factors from teacher surveys and interviews. Resources and leadership were critical to supporting and sustaining instructional reform. In particular, teachers and administrators identified time for planning and learning together, expertise from within and outside the school, and social resources from supportive communities of teachers. Leadership needed to be responsive to resource allocation and distributed throughout the school, with teachers given leadership opportunities.

As part of a larger survey into teachers' problem-solving beliefs and practices (Anderson, Sullivan & White, 2004), primary school teachers were asked to respond to the following question, "what do you see as the professional development needs of teachers at your school in relation to problem solving"? To compare the perceived needs of primary school teachers with those of secondary teachers, a group of secondary mathematics teachers were asked the same question at the beginning of a workshop on Working Mathematically. Analysis of teacher responses is presented with recommendations from both groups of teachers.

Primary School Teachers' Views

The 130 survey responses from primary school teachers in NSW were read and comments grouped into three broad areas with further subcategories formed as indicated in Figure 1.

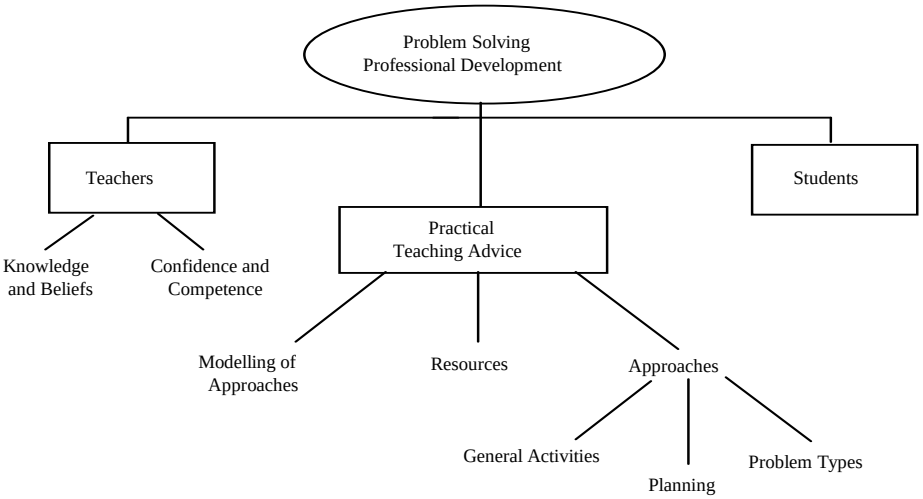

Figure 2. Classification of primary school teachers' comments about the problem-solving professional development needs of school staff.

Teachers. Twenty-six comments (20% of responses) were made about teachers' knowledge and beliefs or their confidence and competence. Of these, 18 referred to teachers' beliefs about mathematics or problem solving and the role of problem solving in learning mathematics. It was suggested by some respondents that teachers in schools needed to rethink their approaches to teaching mathematics and to move from more formal approaches to innovative, creative methods. However others indicated that teachers needed to be more aware of the benefits of problem solving in the mathematics curriculum, since in their view problem solving is not seen as legitimate mathematical activity.Problem solving needs "credibility raising - it's not seen by teachers of Years 4 to 6 as serious maths".

Another group commented on teachers' confidence and competence suggesting that teachers needed support and encouragement. One teacher described the lack of control of students' learning that can happen in problem-solving classrooms. She stated

> A lot (of teachers) are scared to do it because they are not sure themselves of what they should be telling the children to do. They feel they are losing a "grasp" on exactly what the children are doing.

This notion of loss of control associated with a lack of confidence to allow students to explore and investigate freely is an important issue in being prepared to adopt problem-solving approaches, particularly if problem solving is considered to be a process of inquiry (Schwan Smith, 2000). In addition, a teacher's competence in relation to problem solving was considered to be a real issue for one respondent who suggested

> Teachers themselves need to develop competence in problem solving processes and then through staff inservicing and interaction, devise appropriate problem-solving strategies for their students.

The comments about teachers also suggested that there is a need to consider teachers' beliefs and knowledge about problem solving, and that teachers need to be encouraged and supported in their efforts so that they could overcome a lack of confidence.

Practical Teaching Advice. Seventy-six per cent of respondents commented on the need for practical teaching advice related to three key suggestions: modelling problem-solving approaches; increasing school resources; and providing information about incorporating problem-solving approaches into the teaching of mathematics through appropriate activities, relevant planning, and the use of a range of problem types.

Some respondents suggested the need to have problem-solving approaches demonstrated to staff by expert teachers. The modelling could take several forms including

peer mentoring, external experts, or instructional videos. One teacher recognised that staff at her school had skills that should be shared with others. She stated

> We would like to see a few staff meetings incorporate peer mentor training, as we have some members of staff who have a lot to offer in regards to problem solving.

These comments indicate that while teachers were aware of recommendations to teach problem solving, it may be difficult for teachers to know what this actually looks like, how to manage a class while students are doing problem solving, and what the role of the teacher might be. This supports Lester's (1994) suggestions that advice to teachers needs to include a clear description of the teacher's role as well as an indication of what a problem-solving classroom looks like. Recently Jones (2004, p. 354) recognised that "there is little research on the role of the teacher in problem-solving instruction" so this is an area that both teachers and researchers recognise as important.

Another significant professional development requirement for many respondents was the availability and accessibility of good resource materials. Twenty-one teachers mentioned resources including books, posters, commercial products, software, and concrete materials. Some suggested the need for demonstration of materials while others indicated the need for more equipment in classrooms. This is an interesting point since suitable materials have been written to support problem-solving approaches and yet according to Clarke (1997), this is not sufficient to encourage adoption of such approaches. Stacey (2003) also commented that the success of good tasks is dependent on the "choice, timing, and detail of their implementation" by the teacher.

The 76 comments about problem-solving teaching approaches were further categorised into those relating to general classroom activities, planning and implementing the curriculum, and specific information about particular problem types. Thirty-nine comments were made about the need for practical, hands-on workshops demonstrating problem-solving approaches. Many teachers described sharing of ideas between teachers and discussing relevant approaches for different year levels. Others described the need for new ideas, fresh approaches and the latest trends. Teachers seemed to be seeking ideas that could be readily implemented. Teachers recognised the skills of their peers and indicated they would value time to share this knowledge and experience. This would support the use of reflection as a necessary component for changing practice and adopting new approaches (Jaworski, 1994).

Nineteen teachers commented on support to integrate problem solving into daily mathematics lessons and incorporate problem solving into the curriculum. Concerns were raised by several of these respondents in relation to adding problem solving into an overcrowded curriculum. It was apparent from some of these comments that problem solving was viewed as an added topic or an additional focus for teachers to incorporate into the curriculum. Several teachers indicated that time to implement new ideas was an issue and that schools needed to recognise this and to make more time available. This included the need for time to plan and implement as well as time to reflect on the success, or otherwise of potential changes.

Respondents wanted ideas about using particular problem types and the role of each in promoting and developing students' problem-solving skills. The comments about particular problem types were influenced by the survey, which listed problem types for teachers. These included application problems, open-ended problems and unfamiliar problems. In particular, there was a desire to learn more about the use of open-ended and unfamiliar problems and to be provided with more examples of these types of problems.

Students. Nineteen respondents (15%) recorded comments about professional development issues that focused on the diverse needs of students in the full range of classrooms from Kindergarten to Year 6. Most of these comments related to students' abilities and in particular about the need to develop the problem-solving abilities of lower achieving students. Another set of responses indicated that language was an issue for many students and this impacted on their ability to interpret and hence solve many problems. Additional needs of staff included management of students and appropriate grouping procedures.

Secondary School Teachers' Views

A group of twelve secondary mathematics teachers attending a workshop on Working Mathematically were asked to complete a survey that posed two questions:

1. Why do we see little problem solving in Year 8 mathematics classrooms?
2. What do you see as the professional development needs of teachers at your school in relation to problem solving?

It is acknowledged that this group of teachers had an interest in Working Mathematically and that their views are not necessarily representative of the range of views of secondary mathematics teachers. However, they provide insights into the issues that teachers face as they try to implement problem-solving approaches. Teachers' responses were classified in a similar way to those for the primary teachers in the previous section. As there was considerable overlap in the issues and needs identified in the responses to each of these questions, one diagram is used to represent the main areas and subcategories (Figure 2).

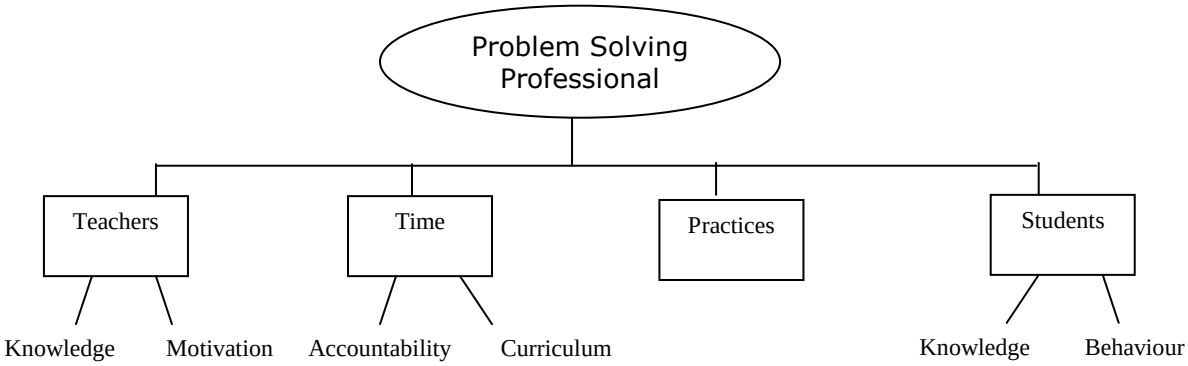

Figure 3. Classification of secondary school teachers' comments about the problem-solving professional development needs of school staff.

Three of the four main areas of need were similar to the primary school teachers' responses. A fourth area that was mentioned by half of the respondents related to the perception that using problem-solving approaches would take up valuable time that needed to be spent of other sections of the syllabus. In particular they described a belief that the curriculum is overcrowded. Associated with this view was accountability of the teachers to cover the syllabus to prepare students for examinations, in particular the high stakes testing that occurs in Years 10 and 12. This view was captured in the following teacher's comment:

The emphasis of accountability with external exams such as SC and HSC and the amount of work required by the syllabuses is such that teachers push through the content rather than "losing" time on enrichment areas such as problem solving.

In relation to the comments about teachers, respondents mentioned knowledge and confidence but also lack of motivation to teach in new ways. This is related to the credibility of the use of problem-solving approaches as noted by one teacher who suggested there was a "need to show 'evidence' to teachers of the advantages of rich tasks". It was also recognised that textbooks frequently determine what teachers do with students so if problem solving is to be promoted, textbooks would need to change. Interestingly one respondent suggested that many secondary teachers enjoyed more traditional practices when they were at school and cannot understand why students do not respond to these practices. The secondary teachers mentioned student behaviour as a constraining factor. In common with the primary school teachers, most of the secondary teachers mentioned the level of understanding of the students. It is clear that for many teachers, a sound basic knowledge of mathematics is required before students are able to engage in investigations and problem solving.

Discussion

The comments made by both groups of teachers indicate that commonly held beliefs about problem solving as an added extra in the curriculum and that students are only able to solve problems after they have acquired basic skills and procedures need to be challenged if change is to occur. The possibility of teaching *through* problem solving, needs to be explored in professional learning experiences. However, teachers did identify issues that should be further considered. Opportunities for teachers to plan and learn together in collaborative environments would further support the development of knowledge and confidence in teaching problem solving. Teachers need to be convinced that providing opportunities for students to engage in rich learning experiences may eliminate poor behaviour and disengagement. How schools and systems address low staff morale and lack of motivation is a challenging issue.

Conclusion and Implications

Given the evidence that students in Year 8 mathematics classrooms experience little complex problem solving, as well as the results from PISA and TIMSS, there is considerable room for change. Regardless of which approach Australian teachers might choose to improve student-learning outcomes, "there needs to be a greater emphasis on explicit mathematical reasoning, deduction, connections and higher-order thinking in lessons" (Stacey, 2003, p. 122). One way to support teachers' efforts is to provide professional development that challenges commonly held beliefs, but at the same time provides the resources for teachers to spend time investigating ways to implement new approaches.

Research into the teachers' role in the problem-solving classroom is also required so that teachers have a clear image of what it looks like in practice. It is time to explore ways that teachers build learning communities within their schools to research their practice, an approach that could be supported by outside experts or academic partners. This is only the beginning. If change is to occur on a larger scale, new ways to research and communicate the findings in meaningful ways are required. Whichever approach is adopted, school systems will need to support the initiatives with the necessary funds and resources.

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