A Comparison of Novice and Expert Views of the Features of Quality Mathematics Teaching

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Results from part of an earlier survey of teachers and academics were compared with student teachers' responses to the same open question. The question asked respondents to detail features of quality mathematics lessons. The students identified many of the same components of effective teaching as did the experienced respondents, but there were some notable differences and omissions. The resulting information has implications for planning of future teacher education experiences. Most importantly, it raises questions about the relative emphases in pre-service mathematics education courses that need to be placed on general pedagogy as opposed to mathematical content and pedagogical content knowledge.

Introduction

Researchers in the Early Numeracy Research Project (Clarke, Sullivan, Cheeseman, & Clarke, 2000) found that about 75% of children entering school could "compare, order and match using the attribute of length" (Clarke et al., 2000). Yet teachers of these young children would spend much of their measurement curriculum time, in at least the children's first year of schooling, on comparing and ordering lengths of objects. Given the "crowded curriculum", focusing on what is already known is questionable.

At Deakin University, we spend a considerable amount of mathematics education time on the study of features of general pedagogy. This is not a separate topic, *per se*, but a component of each topic, particularly in the introductory units. One must ask whether this expenditure of time on development of pedagogical (as opposed to content or pedagogical content knowledge, to use the categories of Schulman, 1986) is warranted. What knowledge of these elements do student teachers bring to their mathematics education units? Do their views on effective teaching vary markedly from experienced teachers' views?

These are the questions that the research reported in this article aimed to answer. They are significant questions because time in any pre-service course is precious, and because (just as in any early learning experience) we do not wish to turn students off learning by focusing on what they already know well. Further, we need to know what knowledge our students have so that we can draw on it as appropriate and build on it in order to further their professional readiness.

Features of Quality Teaching

Sullivan and Mousley (1994, 1997) noted that previous to their project entitled *Features of Quality Teaching* there had been few research projects aimed at identifying aspects of effective mathematics teaching. Today presented a different picture, with most Australian states supporting projects with this aim. For example, (a) the *Numeracy Research in NSW Primary Schools Project* subtitled "What's making the difference in achieving outstanding primary school learning outcomes in numeracy?" (b) Queensland's

B. Barton, K. C. Irwin, M. Pfannkuch, & M. O. J. Thomas (Eds.) *Mathematics Education in the South Pacific* (Proceedings of the 25th annual conference of the Mathematics Education Research Group of Australasia, Auckland, pp. 489-496). Sydney: MERGA. ©2002 MERGA Inc.

What elements of learning environments promote enhanced student numeracy outcomes? (c) South Australia's *Numeracy Research in Primary Schools* project exploring practices that have led to improvement results, and (d) Western Australia's *Numeracy Research Project* "unravelling" factors that make a difference to numeracy outcomes. These initiatives were preceded by the same focus of interest in the United Kingdom (e.g., Askew et al., 1997. Askew & William, 1995; OfSTED 1995, 1996, 1997, 1998) and the United States (e.g., Borich, 1996; NCTM, 2000; Wood & Sellers, 1997).

The Original Survey

Sullivan and Mousley (1994) found that that there was some consensus amongst their subjects about features of effective teaching. The prompt below was administered to 125 experienced teachers and mathematics education academics (called the teachers for the rest of this paper):

> Imagine a mathematics lesson, at any year level, where the students are learning to estimate the weights of various objects, or to add fractions, or to record given information as a graph. Please write down the most important characteristics that a *quality* mathematics lesson on any of these concepts/skills would usually have.

Details of the data-handling and sorting process are outlined in Mousley, Sullivan and Waywood (1998). The researchers identified major components of quality teaching, along with the sub-categories listed in Figure 1.

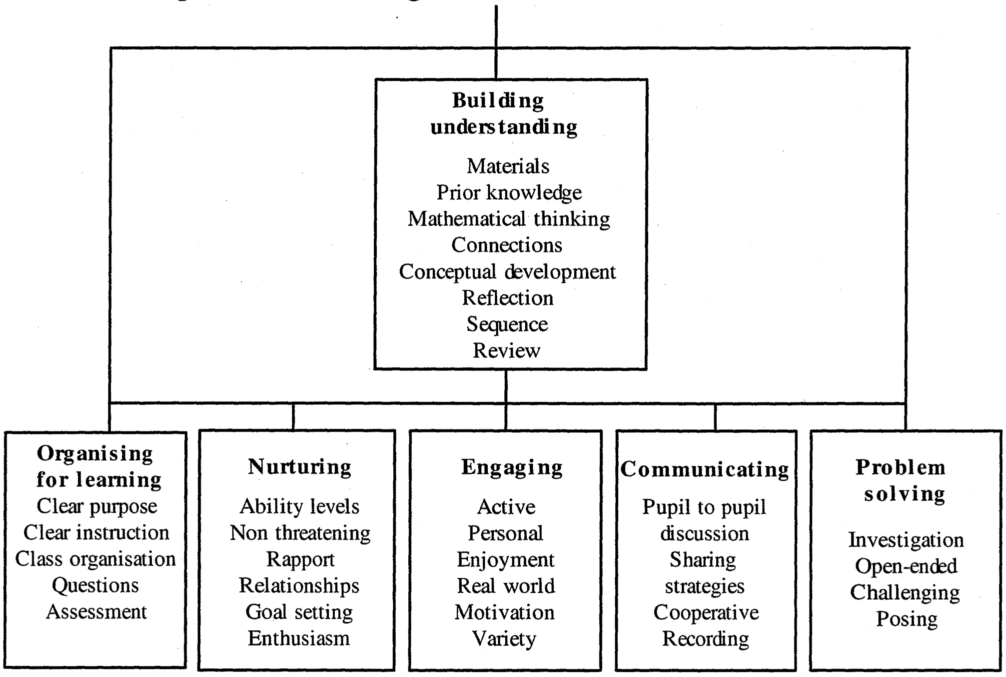

Figure 1: Features of quality teaching (from Sullivan & Mousley, 1996, p. 13)

A Comparison with Pre-service Teachers' Perceptions of Quality Teaching

It is generally assumed that student teachers bring to their courses limited and limiting ideas about the ways that mathematics should be taught. Schuck (1999) would have struck a chord with many of us with the title of her paper "Driving a mathematics education reform with unwilling passengers". Schuck found that many of her own students held beliefs about mathematics and pedagogy that constrain their access to alternatives. She realised that her task was to make students more aware of their beliefs as well as the implications of these for their future as teachers. When discussing the implications of this research for the ways that we might plan for and evaluate our own tertiary teaching, we decided to find out whether perceptions of quality mathematics teaching vary between experienced teachers and novices. Our research question became "Do our own students hold beliefs that are likely to constrain their access to effective teaching practices?" Given that we could gain access to the Mousley and Sullivan data as a basis for this comparison, we used the same open-ended instrument as above.

For this investigation, our subjects were 123 teacher Education students. About eighty were entering the second level of a four-year undergraduate degree, but had studied only two Education units because the first year of their course is heavily weighted with general arts and discipline area studies. This group had experienced one practicum round. The others were postgraduates who had just entered our pre-service two-year end-on course (called the students for the rest of this paper).

All of the students were new to mathematics education. They were in the first few weeks of their first mathematics education unit, with more units to follow in subsequent years. These were *our* entry students, so it was their knowledge that was relevant to our planning and teaching in order to help us with delivery of appropriate content and activities. We will repeat the exercise at the end of semester to gauge how their beliefs have changed as a result of their mathematics education experiences during the semester—including lectures, tutorials, group and individual assignments, reading tasks, preparation for the exam, and a 10–15 day practicum with some mathematics teaching.

The students were shown the open-ended prompt above and given class time (five minutes) to write their responses. These were typed and sorted into the same categories used by Sullivan and Mousley shown in Figure 1 above. The only change in method was that the students responded only to this prompt whereas the teachers had gone on to a more structured section of the questionnaire.

Results

This paper focuses both on comparing the numbers and proportions of responses in each category and sub-category as well as their nature. There are three points to note regarding the numbers reported below. First, as in Mousley and Sullivan's data sorting, some sentences or phrases were entered into several sub-categories. Second, although by coincidence the number of students (123) was very close to the number of teachers (125), the students wrote a lot more comments (529) than did the teachers (384); perhaps because they had been given a whole sheet of paper, and/or they did not have three pages of structured questions following this initial open one. Thus we have reported in the results below not only numbers of phrases but also these numbers expressed as percentages of responses from each sample. Third, the data were qualitative so we make no claims about statistical significance of differences noted, seeking only to give a sense of these. Also, while we know what teachers and students wrote, we do not know why they focused on those aspects of teaching. In some cases it was even difficult to infer what they meant. For example, does "Explain clearly" refer to conceptual or procedural explanations? We acknowledge the limitations of the data gathering and analysis processes in both studies in this respect.

Comparison of Categories

The number of comments allocated to each category by the teachers and the students is summarised in Table 1 below. Results and discussion for each sub-category follow, although space did not allow tabular presentation of these.

Table 1
Number of Entries Under Each Category

Sub-category	Teachers		Students	
	n[1]	%[2]	n[1]	%[2]
Building understanding	106	28	167	32
Communicating	75	20	66	12
Engaging children	74	19	174	33
Problem solving	53	14	11	2
Nurturing children	44	11	78	15
Organising for learning	32	8	33	6
	384	100	529	100

[1] Number of comments allocated to the relevant category.
[2] Percentage of all responses by the relevant sample, rounded to the nearest whole number.

The table shows clearly that there are similarities between numbers of comments made by teachers and students for some categories. *Building understanding*, *Nurturing* and *Organising for learning* showed similar patterns of response, although these mask differences in sub-categories (see below). Teachers showed more awareness of the importance of forms of *Communication*, and made many more comments about *Problem Solving*, a strategy that was becoming a popular at the time of their survey. However, the students gave the notion of *Engaging children* more emphasis—possibly in response to their own learning preferences.

Comparison of Sub-categories

Building understanding. This term is used in recognition of "particular understandings to be developed, and of strategies to achieve this end by building on existing knowledge, using materials to explain and clarify concepts, choosing appropriate sequences, helping students to make connections, forming relationships, and knowing the meaning of terms. There is a strong inference of teacher decision, teacher direction, teacher explanations and teacher control" (Sullivan & Mousley, 1994, p. 9).

For *Use of materials* T = 36 (9%), S = 35 (7%); *Use of prior knowledge* T = 21 (5%), S = 29 (5%); *Mathematical thinking* T = 15 (4%), S = 17 (3%); *Making connections* T = 14 (4%), S = 14 (3%); *Conceptual understanding* T = 10 (3%), S = 54 (10%); *Encouraging reflection* T = 6 (2%), S = 3 (1%); and *Use of review/closure* T = 4 (1%), S = 15 (3%).

These figures general demonstrate a relatively close alignment in the thinking of teachers and students. A surprising difference related to the development of conceptual understanding, with many more student comments than teacher comments about the importance of this. Some examples of students' comments follow:

> Spend one-on-one time with kids to try to make sure they understand the concepts—no point in moving on if they don't. Make sure they understand why as well as how they are to do it.

> Learn, not regurgitate.
>
> Assuming the context to be fractions, a lesson that fleshed out the key concepts for the student would be beneficial. For instance the use of visual clues and divisible objects would seem likely—basic ideas that lead the children into forming their own patterns around the ideas.

The number of student comments on the importance of review and lesson closure may have been the result of students learning about lesson planning in Education Studies.

Communicating. This category includes "statements related to opportunities for talking, explaining, describing, listening, asking, clarifying, sharing, writing, reporting, and recording" (Sullivan & Mousley, 1994, p. 12).

For *Discussion between pupils* T = 34 (8%), S = 5 (1%); *Sharing strategies* T = 20 (5%), S = 10 (2%); *Co-operative situations* T = 15 (4%), S = 45 (9%); and *Recording* T = 6 (2%), S = 6 (1%).

As would be expected, the teachers here valued discussion and the sharing of strategies—two points emphasised frequently in professional literature and development activities. It would be interesting to probe further how both the teachers and the students define *Co-operative situations* and to try to find out why relatively more student comments were made. These comments included:

> All lessons would have opportunities to work in pairs or groups, to work out answers, enhance understandings with each other through experimentation and discussion with the teacher.
>
> Team work (of children) to find answers—bouncing ideas off one another.
>
> Occasional group work could aid in the brainstorming of solutions.

Engaging Children. This category is generally about students' involvement in their own learning. Included in it are both physical and mental forms of engagement such as keeping children actively and productively involved in thought-provoking activities, as well as more affective factors such as motivation and interest.

For *Active involvement* T = 34 (8%), S = 31 (6%); *Personally relevant* T = 16 (4%), S = 30 (6%); *Enjoyment* T = 5 (2%), S = 41 (8%); *Real world* T = 7 (2%), S = 42 (8%); *Motivation* T = 6 (2%), S = 18 (3%); and *Variety* T = 6 (2%), S = 12 (2%).

Thus while there was general agreement between teachers and students in four of the sub-categories, notable differences were evident in relation to both *Enjoyment* and the use of *Real world* contexts. We were not surprised that students seemed aware of the need to make mathematics enjoyable as well as clearly useful. Their sentences included:

> Fun—the more interesting you make it the easier to learn. Turn it into an enjoyable activity rather than a mathematical chore.
>
> Ensure all children enjoy and understand the activities and see how they apply in everyday life. Get all of the class involved in meaningful activities. Not just pencil and paper.

Problem solving. The term problem solving has been used to mean many things in many situations. It is not surprising that some variation was evident in responses

For *Use of problem-solving tasks* T = 27 (7%), S = 7 (1%); *Use of open-ended tasks* T = 14 (4%), S = 1 (<1%); *Use of challenging activities* T = 6 (2%), S = 2 (<1%); and *Problem posing opportunities* T = 6 (2%), S = 1 (<1%).

Note that there were many more teachers' comments than students' comments about all aspects of problem solving. The problem solving movement was influential at the time that teachers completed the survey and there was a blossoming interest in open-ended tasks and investigations. Perhaps the students of those times now see such activity as a "given" in mathematics. Despite the small number of comments, those made were insightful. For example:

> Provide challenging problems to convey the message that all problems can be attempted, and discuss creating means of solving them.
>
> Have problem solving activities where kids have to think constructively / critically and also let the students create their own real life problems and solve them.

Nurturing Children. Most of the descriptors categorised under this heading were related to the teacher being sensitive to the needs of the "whole child" or "individuals".

For *Catering for levels of ability* T = 11 (3%), S = 35 (7%); *Non-threatening atmosphere* T = 10 (3%), S = 22 (4%); *Rapport with children* T = 9 (2%), S = 11 (2%); *Enthusiasm* T = 8 (2%), S = 2 (1%); *Personal relationships* T = 4 (1%), S = 4 (1%); and *Goal setting and negotiation* T = 2 (<1%), S = 4 (1%).

The exception to the pattern of similarity—the emphasis by students on catering for a range of abilities—could be accounted for partly by the emphasis on equity issues and inclusive curriculum in first year Education Studies as well as by more focus on this in the broader society in recent years. Some representative comments here are:

> The teacher must be patient and understand that each child learns at a different pace. The teacher should have some background knowledge of what each child's level of understanding is.
>
> Be patient—some children might not understand the task at hand so be prepared to spend time with those who are struggling.
>
> Make sure everyone knows they can ask questions if they don't understand. Try to ensure everyone understands what they have to do. Follow up at the end by asking random students what they did, what answer they got and what does it mean. Doing this rather than saying "Who knows the answer?" may help identify children with problems, rather than them hiding that they don't understand so that the smart children tell everyone the answers and the confused children don't get an explanation from someone who might also be confused.

Organising for Learning. This component refers to actions designed to keep students working towards achieving a lesson's goals, decisions made by the teacher about a specific focus and a commitment to pursuing that focus, and communicating the focus to the students.

For *Clear purpose* T = 14 (4%), S = 8 (2%); *Clear instruction* T = 7 (2%), S = 20 (4%); *Organisation* T = 4 (1%), S = 2 (<1%); *Assessment* T = 4 (1%), S = 2 (<1%); and *Questions* T = 3 (1%), S = 1 (<1%).

The noteworthy differences here lie in clarity of purpose (which the teachers recognised more), and of instructions (which the students emphasised more). Perhaps this reflects traditional roles and experiences. Students' comments in this category included:

> Clear simple directions so as not to confuse. Straight-forward, detailed explanation of the topic.
>
> A clear explanation of the class objective.
>
> Activities where students can see for themselves the purpose of the concept.

Emerging Points

An emphasis on time. The only factor that was not covered explicitly by Sullivan and Mousley but that the students mentioned a number of times, was the need to give children time for learning.

> Allow enough time for children to work out the maths problems—ensure there is not time pressure that may mean children don't get long enough to think creatively about the answers.

Time—do not rush.

Perhaps teachers see time as more of an inevitable constraint rather than an aspect of quality teaching; and once again, the students' comments may reflect on their perceptions (as school students) of the pressure and limitations imposed by teachers' and curriculum developers' expectations.

The quality of responses. Several aspects of the students' responses pleasantly surprised us. First, some showed that they had been analytical and critical observers of classroom practices during their practicum periods.

> Teacher demonstrating the "how to" on the board followed by students doing either workbook or photocopied examples to gain an understanding of the subject matter. This is what I have seen on teaching rounds. However, for me it is more important that each student understands the concept and can also relate it to everyday life and hopefully make use of the concepts.

Further, many students seemed both insightful and articulate. They demonstrated maturity in professional knowledge as well as the language used to express it.

> The children are encouraged to be imaginative and innovative in approaches and techniques.
>
> Let them experience the ideas.
>
> Have two different ways (more if possible) to explain a concept in case some children interpret and understand the information differently than others, or differently from what we expected.

Some demonstrated a willingness to engage in reflections about heir own teaching, making comments about on-going learning as a reflective teacher:

> Discussion of difficulties, what was hard and why, to improve teachers' understandings of children's abilities and of how the teacher may understand her or his own presentation of the mathematical concepts.

A number of responses put a focus on deeper levels of understanding.

> For fractions and mass, incorrect examples can be shown so students can differentiate and hence understand the correct ideas better.
>
> Physical example of abstract theory.
>
> At primary age, learning mass may involve using various size containers. This enables the kids to explore mass/weights for themselves to discover various characteristics and hopefully come up with general rules to be used.

A final pleasing point was that many students emphasised learning and linked this with generalisations about appropriate teaching strategies.

> Learning is the foundation of all good lessons. There is no point having good teaching approaches and activities that do not lead to extra learning.
>
> Quality maths lessons are all about concepts and exploration. They need to do the thinking about the maths at school. Students can do the exercises at home because the repetition might help a child remember what they have learnt.

Conclusions and Implications

An exercise that we thought would be useful for our planning and evaluation of unit foci and content proved more fruitful than expected. It has given us insights into many of the students' understandings and perspectives, their abilities to articulate and share these, and also some needs (such as attention to uses of problem solving). It was also reassuring that their responses mentioned the full range of areas that experienced teachers and academics mentioned.

However, we realise that while many of the comments demonstrated significant knowledge and maturity in thinking, there are a number of areas that need our attention. Not all students demonstrated a strong grasp of aspects of effective teaching. We also need to consider that even if students have beliefs about the worth of particular aspects of classroom practice; they may not have a strong grasp of the underpinning theoretical bases for particular components of quality teaching.

It is clear that more research is needed to find out the extent to which students hold a good level of understanding, and that we need to consider how we can make use of this knowledge. Also raised are questions of how best to organise learning for those who do not enter the course with adequate understanding of general mathematics pedagogy while still catering for those who do.

We believe that the most important point arising from the findings is that in many areas the novices' comments were very much like those of the experts, and were made in similar proportions. This raises questions about the relative emphases that need to be placed on pedagogy as opposed to mathematical content knowledge and pedagogical content knowledge in teacher education courses—ours specifically but perhaps pre-service mathematics education courses more generally. The data suggest that we could focus less on quality teaching in general and more on ideas related to the learning and teaching of specific content.

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