DEVELOPING NEW STATISTICAL CONTENT KNOWLEDGE WITH SECONDARY SCHOOL MATHEMATICS TEACHERS

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This paper describes a pilot study exploring the acquisition of new statistical content knowledge by teachers, which is now needed as a result of curriculum change. The teachers involved in the study formed a professional learning community where their learning needs with respect to changes in the statistics curriculum were identified and workshops presented to help meet these needs. In this paper teachers' understanding of new statistical content knowledge and learning experiences are reported. Initial findings support previous research into how teachers learn and show that new content knowledge is not automatically gained through their participation in professional development.

INTRODUCTION

Statistics is becoming a major component in New Zealand's school mathematics curriculum. The 1992 mathematics curriculum had a major change in terms of the statistics to be taught and the way that it was taught. The new 2008 curriculum has brought further change in the statistics area. The 2008 curriculum has evolved over a number of years. Many teachers, students, parents and other key stakeholders were involved in a thorough consultation process. During the consultation one of the key issues that came up for mathematics teachers was the change within the statistics strand. Teachers were generally in favour of the direction of the change, but they felt the challenge for them was the new statistical content knowledge. In particular, experimental design, re-sampling methods, randomisation, relative risk, variation, exploratory data analysis and statistical inference were areas teachers felt they needed support in from both knowledge and teaching perspectives.

Therefore questions arise such as: "How does the teacher prepare to teach something never previously learned? How does learning for teaching occur?" (Shulman, 1986, p. 8). These questions are in regard to beginning teachers, but they are equally applicable to experienced teachers when faced with curriculum change. Curriculum change and the consequent need for professional development is always part of the fabric of education. According to Goldman (2001) and Wilson and Berne (1999) effective professional development is about increasing teacher knowledge within a climate of trust. For teachers to engage in professional development they have to identify that they have a need and therefore a reason for the professional development, and this should be embedded in a culture of teaching and learning.

Teachers come to the professional development table with varied and different backgrounds. Their level of expertise in mathematics will be different as will their level of expertise in statistics. They may not have learned the content they now need to teach or how to teach in a way to meet the requirements of the curriculum (Begg, 2005; Alder, Ball, Krainer & Lin, 2005). This wide range of experience and expertise adds a further dimension to the professional development arena. Wilson and Berne (1999) extracted from their examination of research that successful professional development included: establishing a community of learning that continued after funding finished; activating teacher learning needs by working with teachers in developing their own knowledge; and the "privileging of teachers' interaction with one another" (p. 195). Goldman (2001) echoes similar ideas for professional development, talking about the need for professional development "grounded in teachers' day to day practice" (p. 22), the need for teachers to improve their knowledge of content of what is important for their students, and the need for reflection by teachers within a supportive community that builds on the varied expertises that the different teachers bring to the group.

This paper reports on a pilot study for which a community of learning was established to research the new statistical content knowledge needed by secondary mathematics teachers and effective ways for teachers to improve their knowledge. The research questions are:

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1. As a result of curriculum change, what new statistical content knowledge do teachers of years 9 and 10 (age 13-15) students need?
2. Did the teachers improve their new statistical content knowledge as a result of being a participant in the workshops?
3. What learning experiences helped the teachers to gain an understanding of the new statistical content knowledge?

RESEARCH METHOD

Action research was the chosen research method. The need to try out multiple approaches, each with its own planning, acting, observing, and reflection phase (Kemmis & McTaggart, 1990), made this a sensible choice as action research follows a cyclic pattern. Teaching by its very nature has a natural action research cycle, but to do action research the planning, implementing, observing and reflecting is done more carefully and more rigorously than one would normally. In the pilot study four short action research cycles were completed, three within the learning community and one within a classroom. This paper will briefly report on the first cycle, part of the second cycle, and the fourth and final reflection cycle. These all occurred within the learning community. The first cycle involved the initial workshop, and the second cycle involved three two-hour workshops, which were held after school.

The number of attendees at each workshop varied from 12 to 19. The teachers were ethnically diverse, had a wide range of experience (two years to over thirty years) and qualifications (statistics majors through to no statistics). The teachers were from 11 different secondary schools, which ranged in size from 500 to 2500 students, and from low to high in socio-economic rating. They were reasonably representative of the teachers and schools in the Auckland region in New Zealand.

The professional development model used within the action research cycle is based on ideas developed from Wilson and Berne (1999) and Goldman (2001). This involved a group of teachers learning together and building a community of practice. Within this setting the teachers identified aspects of the new content on which they wanted to work or with which they needed help, thus giving a clear purpose for the professional development. The teachers were encouraged to discuss their thoughts and ideas with one another throughout the workshops, and time was given for self-reflection and reflection with others. One of the main principles of the workshops was for the teachers to experience an activity that could be used with or modified for their classes. Teaching activities were developed for the group using previous research (e.g., Pfannkuch, 2006; Watson, 2006). Teachers' responses to open-ended questionnaires, email and journal questions were collected as data. Spreadsheets were used to categorise and analyse the data qualitatively.

RESEARCH CYCLE ONE

In the initial workshop teachers undertook a number of activities to try to identify the areas on which they wanted to work in the subsequent workshops. Initially they were asked to brainstorm ideas about topics with which their year 9/10 (age 13-15) students had difficulty in statistics. Following this activity, teachers were given a copy of the statistics achievement objectives and asked to identify where in the Problem, Plan, Data, Analysis, Conclusion (PPDAC) cycle (Wild & Pfannkuch, 1999) they fitted. The teachers then focused on the achievement objectives for year 9/10 and identified the words or objectives that they (1) had no idea about what they meant; (2) were unsure about what they meant; (3) had an idea about what they meant but were unsure of how to teach; or (4) were reasonably sure about what they meant but would like to do more work in those areas.

RESULTS AND ANALYSIS

The information from the initial workshop was collated and used to make decisions on what was to be covered in the next three workshops. The teachers colour coded either a whole objective or words within an objective. Two methods were used to rank the different objectives and/or words. Method one was a weighted rank, and method two was a straight count rank. Altogether 18 areas were mentioned. The top six areas by both methods are listed in Table 1.

(Six areas were selected as there was a clear difference between these six and the remaining areas.) A total of 12 teachers were present at the first workshop and contributed to these data. The words in italics are the particular part of the achievement objective that was identified.

Table 1. Achievement objectives/words identified as needing support

Achievement objective	Weighted Total	Rank	Count Total	Rank
Considering sources of variation	28	1	11	2=
Using multiple displays, and *recategorising data* to find patterns	25	2	11	2=
Gathering and *cleaning data*	22	3	12	1
Comparing sample distributions visually, using measures of centre, spread and proportion	15	4	7	5=
Presenting a report of findings	14	5	9	4
Determining appropriate variables and *measures*	13	6	7	5=

Three areas stood out in answer to the first research question about new statistical content knowledge teachers felt they needed: considering sources of variation, recategorising the data and cleaning the data. These areas gave a focus to the workshops in research cycle two.

RESEARCH CYCLE TWO

For the purpose of this paper only workshop two on considering sources of variation will be discussed. Each of the three workshops was planned following a similar format. The evidence presented is based on the written responses from the teachers. The plan for workshop two is outlined below. This workshop also included determining appropriate variables and measures (rank 5 in Table 1):

- Feedback on initial workshop; topics to be covered and why.
- Write initial ideas on what considering sources of variation means.
- Discussion within smaller groups about the meaning of considering sources of variation.
- Discussion starter: “There is too much violence on TV”. How might we measure violence? What are some sources of variation?
- Further group work using the ideas developed in the discussion starter on the topics fitness, water quality, and healthy lunches.
- Reflection - respond to journal prompts.

RESULTS AND ANALYSIS

This section presents the results of the participating teachers’ responses in the second workshop and in answer to the second research question: Did the teachers improve their statistical content knowledge as a result of being a participant in the workshops? Evidence was collected from the teachers before the workshop started and at the end of the workshop. Before the start teachers wrote their initial ideas on what they thought considering sources of variation meant. At the end they wrote in their journal in response to specific prompts.

Before the workshop, teachers’ initial ideas on considering sources of variation were varied. Five main ideas emerged: (1) Recording method: how the measures are taken (e.g., teacher quote: “measurement same tape, measure same time of day”); (2) Sample variation: sampling method/ collecting different samples, sample size (“variation in the data could be about collecting only a sample and knowing that this is not nec. representative of the whole”); (3) Experiment: controlling variables in an experiment (“control of variables in expt.”); (4) Values vary: within a single variable data set (“height variation within the single variable data set”); and (5) Survey bias: variation arising from the questions that are asked, wording effects and interviewer bias (“how interview questions are asked”).

At the end of the workshop, in response to a journal prompt about their learning, seven out of the nine teachers who responded indicated that in their opinion there was a positive movement in their understanding of the content covered in the workshop. For example, one of the teachers wrote, "[I was] less sure of variation and sources of [variation], could not give a large variety of examples. This was clarified through group discussion." Another two teachers expressed quite different opinions. One felt that he was "… already clued up about terminology and language …" while the other one felt more confused. She wrote, "I think I am now more confused … is variability of data saying that people's feet length vary and most people have feet about so long and … as in getting towards the idea of distribution or is variability only about variability caused by the way the data is collected … or both?"

Unfortunately the prompt did not elicit new or improved meanings of the expression "considering sources of variation" for all the teachers, as some only gave their opinion on whether they understood the term. Therefore as a result of the limited feedback in their journals, I emailed some of the teachers and asked them to give a response to the question: When considering sources of variation: what does this now mean to you? The responses from the email question, along with the journal responses, were then categorised and compared to their responses before the workshop. The results are summarised in Table 2. In the table the coding identifies the quality of the response. Some teachers just made mention of a particular source of variation with little or no depth of explanation. ○ indicates an idea was mentioned before the workshop, and □ indicates an idea was mentioned after the workshop. Some of the comments were more in depth and appeared to show a deeper understanding of sources of variation. ● indicates a more in depth idea before the workshop, ■ indicates a more in depth idea after the workshop.

Table 2. Teacher understanding of *considering sources of variation* before and after workshop

Idea Teacher	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Recording before		○	○					○	○	○		●	○	○		
Method after	□	■	■	□	□			□	□				□		□	□
Sample before		○	○	○				○	○	○	○	○			○	○
Variation after	□		□	□	■											□
Experiment before		○	○		○	○	○		○		○					
after			□	□		■		■								
Values vary before		○												○		○
after		□						□	□				□		■	□
Survey bias before			○							○		○	○			
after		□	□													
Total before	0	4	4	1	1	1	1	2	3	3	2	3	2	2	1	2
after	2	3	4	3	2	1		3	2				2		2	3

When comparing teachers' responses before and after the workshop it seemed that some had widened their view of considering sources of variation, and some had deepened their understanding. For example, before the workshop Teacher F wrote "all the things that contribute to the change in the variable" and after she wrote:

> Sources of variation and how to control them: anything that might unduly influence results of an investigation. How would we compare bottled water vs tap water? If these are the two variables, then need to look at sources of variation. Examples: temperature, time of day, packaging, clarity, taste. Ideas for control: keep in same fridge, measure same amount out, in same drinking vessels, same time of day, blind tasting.

This example shows a deepened understanding of considering sources of variation within the experiment idea category (Table 2). Of the eleven teachers whose definitions I could categorise, six of these now considered more ideas (a wider view) when discussing sources of variation (see total in Table 2), and three other teachers (Teacher B, C and F) had deepened their understanding after the workshop in at least one of the idea categories (Table 2).

FINAL REFLECTION CYCLE

The introduction of the 2008 curriculum requires teachers to learn new statistical content knowledge, and therefore I was interested in what learning experiences in the workshops were effective for teachers to gain new content knowledge. Throughout each of the workshops the teachers had the opportunity to respond to the prompt: What processes/activities/interactions happened today to help you develop/get to know these new terms/ideas? As well as the responses from the individual content workshops, teachers were specifically asked in the final workshop session to reflect on what helped them to learn, what activities helped most, what activities helped least, whether they needed to learn all the content covered and how confident they felt about teaching the different ideas covered in the workshops. For the purpose of this paper I will focus on what helped the teachers to learn in answer to research question three: What learning experiences helped the teachers to gain an understanding of the new statistical content knowledge?

RESULTS AND ANALYSIS

The participating teachers offered many suggestions as to what helped them to learn. For example, working in a learning community, having to actually do the activities in the workshop, working with others, having discussions and hearing what others think, having time to reflect, using data cards (Watson, 2006), using *Fathom* (Key Curriculum Press Technologies, 2000), and a focus on language. The two most commonly mentioned ideas were actually doing the activities in the workshop (nine out of twelve people), working with others, having discussions, and hearing what others think (eight people). Examples of responses for actually doing the activities include: “going through the activities with other maths teachers” and “I liked having the individual time to explore and extend ideas - you gave us space and time to do this”. Examples of responses for working with others include: “hearing other teachers and things they did” and “open professional discussions, with people honest enough to say there were concepts/terminology not properly understood.”

Teachers’ thoughts on the other ideas mentioned above include using Fathom (five people) and using data cards (four people). For example: “The most useful activity was having data that we laid out on the table into different categories”, “ data cards (the ‘concrete materials’ of statistical thinking) because they reminded me how good it is for students to be able to touch, move around objects when they are learning” and “the use of technology was helpful for data inspection; quickly established concepts.” Teachers also mentioned the learning community was something that helped them to learn (four people): “Being among peers who were helpful and non threatening – the fact that I could admit no knowledge and people around would help – to some extent we were all in the same boat.” Some of the teachers also mentioned the fact that the workshops were developed around what they didn’t know (two people): “Great to have input into what the sessions were about – more meaningful to do a workshop where you have a learning need yourself.”

The evidence here supports the ideas of Wilson and Berne (1999) and Goldman (2001) about what makes good professional development. Building a learning community provides a foundation on which to build the rest of the work. Working through the activities, discussion in pairs and within a group, sharing ideas and conclusions with one another, listening to what others had to say, helped the teachers with their learning of the new statistical content knowledge. The data cards and technology such as *Fathom* were types of activities that the teachers enjoyed and felt were useful. The fact that the teachers were working on content knowledge that they had identified themselves as needing was also important.

DISCUSSION

This initial study reports preliminary observations. More careful wording is needed in the journal prompts and other instruments for determining teachers level of knowledge may need to be considered, for example, assessment tasks and interviews.

Professional growth is part of every profession and in education is ongoing. As teachers strive to make their students lifelong learners, they too must continue to be lifelong learners for

this is where real understanding takes place. When working with the teachers to answer the first research question, it appeared that while teachers had varied needs some areas were new to most. The three key areas needing work were considering sources of variation, cleaning data, and recategorising data, which became the focus for the workshops.

The results for the second research question suggest that teachers may have slightly improved their new statistical content knowledge. However, the depth and breadth of this knowledge is varied. The findings show that nearly all of the teachers either widened their knowledge or developed a deepened understanding in relation to considering sources of variation. This pilot study's preliminary findings suggest that teachers' understandings are still limited, and ongoing support is needed for the teachers, both within the learning community and within their practice. Teachers' knowledge may deepen further when they teach the content to their students. The very act of teaching the content may reveal students' misconceptions and common difficulties, and hence teachers' reflections on their teaching may further deepen their understanding of new content knowledge.

While there is no evidence at this stage that the learning experiences in the workshops made a difference to teachers' understanding of the statistical content, the teachers' perception was that their understanding had improved. In particular, they believed that the opportunity to actually do the activities, to talk with other teachers, and to discuss the work they were doing did make a difference to their learning. These findings support Wilson and Berne's (1999) examination of research on successful professional development. Building a professional learning community provided a foundation for learning to take place for these teachers. The chance to discuss ideas and to challenge their thinking appeared to move them to a more powerful place in terms of their understanding of the new statistical content knowledge needed to teach year 9/10 statistics. The ongoing nature of the workshops, compared with the one-off workshop also seemed to help cement the willingness and need to learn. The teachers involved in the pilot study wish to continue to be involved in the research in the next phase. This would suggest that they enjoyed the experience in the learning community and want to continue to be involved in order to learn more to improve their understanding of the new content, learn more in order to improve their teaching, and continue to be part of a group that is researching and developing a shared understanding of the new statistical content knowledge.

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