Beliefs About Teaching Stochastics Held By Primary Pre-service Teaching Students

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This paper explores some observed confusions held by pre-service teachers about concepts of probability and statistics. The writer uses information about confusion and misconceptions held by pre-service teachers gained by examination of teaching assignments written by her tertiary students. It considers some other research in this field and makes some suggestions about what steps may be taken to provide pre-service teachers with a better understanding of stochastics.

Introduction

The primary pre-service teaching course at the University of South Australia uses the *National Statement on Teaching Mathematics for Australian Schools* (AEC, 1991) and the related documents *Mathematics A Curriculum Profile for Australian Schools* (AEC, 1994a) and *Mathematics Work Samples* (AEC, 1994b) as major references. They are used because they provide common planning documents for students and the teachers who will supervise the practicum.

The mathematics curriculum subject offered to these students is of the 'pressure cooker' variety—only 100 contact hours over a four year period with practicum experience spread throughout the course. The emphasis of the subject is on childrens' cognitive development, and the mathematics of the primary curriculum as set out in the National Statement and associated documents. Students are encouraged to use a wide range of teacher reference books for additional lesson ideas.

Methodology

This paper examines the methodology used with the above group of students and discusses some of the difficulties that these students, who were in the second year of the course in Semester 2, 1996 experienced. They spent nine weeks in lectures broken half-way by four weeks on practicum. Students were required to prepare lesson plans for a mathematics topic which they would then teach during the practicum. This planning was generally done with the support of their supervising teachers. The task required students to plan, teach and then to reflect on a series of four lessons. It is this task that will be discussed in this paper, because such responses indicate important beliefs by students about the teaching and learning of Chance & data.

Of the group of 180 students, 23 chose Chance & data as their topic and it is from these 23 that the examples in this paper are taken. Five sets of lesson plans referred solely to the *National Statement* and *Curriculum Profiles* as source material while the remainder also referred to other linked documents or related references.

The students, however, found these documents very difficult to work with overall and the Chance & data strand caused particular difficulties. Russell & Mokros (1990), Shaughnessy (1992) and Greer & Ritson (1993) have all reported similar difficulties by students in other systems using similar curriculum documents. The majority of students used the outcome statements from the *National Statement* and the *Profiles* for their lesson planning. Both are seen as authoritative documents to be followed to the letter. In an analysis of the documents we proposed that '[O]utcome statements emphasise one aspect of the learning process. They are absolute and isolated. They do not present each outcome in the wider context of a child's mathematical thinking.' (K. & J. Truran, 1994). The drawing together of individual aspects of mathematics into a cohesive whole is a long (cognitive) process which many children will not comprehend before they finish primary school. Students' comments, my observations and other research, for example (Green, 1982) suggests that this difficulty does exist and I shall argue here that it extends to pre-service teaching students.

Student Background

The majority of the students discussed here have a limited mathematics background. Some claim to have completed Year 12 mathematics; however, the majority of these have studied Business Mathematics which should be called 'Business Arithmetic', based as it is on simple calculations involving number, percentages and decimal fractions. Very few students have studied the traditional, academic Maths 1 and 2 courses. Therefore, pre-service students come to this subject unsure of their own mathematics knowledge and with strong misconceptions about topics like Fractions, Algebra and Number. A few openly profess to hate mathematics and related subjects.

Furthermore, the university's policy of exposing all teaching students to both junior and upper primary classes was viewed with alarm by some, and by real fear by most of those students who had intended to specialise in junior primary teaching and had made this decision because they viewed maths for young children as being 'easier'. Southwell (1995) claims that both cognition and affect are factors in mathematics learning, and points out that if a student feels to be lacking in the necessary ability to achieve good results in mathematics or does not consider mathematics to be very important then this student will not feel confident enough to try to achieve good results. One student who confessed to having taught only one mathematics lesson during her 4 week practicum was delighted by this and told me about it very proudly.

Edwards (1996) is carrying out a survey among pre-service primary teachers in New Zealand in respect to teacher knowledge and confidence in teaching statistics. He observes some anomalies in his study between teachers' perceptions of their own statistical ability (or lack of same) and their high teaching confidence. In fact, in his study, few saw their lack of ability as a problem for their students. I have also observed this among the students discussed in this paper, who claimed, among other things that because the outcome of random events is non-deterministic then the approach to teaching probability doesn't matter and the children will 'pick it up sooner or later anyway', others believe that asking children to*predict* an outcome is sufficient criteria for teaching probability. The non-deterministic aspect of probability caused students other difficulties. Many stated that of all the topics Chance is hardest to teach because 'there usually wasn't a right answer'. Throughout the workshops before their teaching practicum some students maintained their view that there are no right or wrong answers in probability, and everyone's contributions are valid. Therefore, (by implication) the kinds of questions used don't matter either. Much of the literature on teachers and statistics education highlights concerns about the lack of 'preparedness' for teaching statistics. Greer & Ritson (1993) believe has its origins in teacher training. The move from lack of training to difficulty in teaching statistics is readily made and assumed by many researchers in statistics education. Hawkins (1990, p. 24) goes so far as to compare the lack of knowledge with a 'disease' which teachers pass on to their students. I now look at details in an attempt to effect a remedy.

Discussion of Results

The following examples demonstrate some interpretations of teaching stochastics by these students. My results examine not the general but the specific in the context where change is still possible by those involved in both pre-service and in-service training. Some suggestions as how that might be done are made in the conclusion of this paper.

Limitations of Formal Documents

There was evidence that the students had not considered the implications of the mathematics of the lessons that they had planned in relation to the age of children in their class and the children's existing experience or pre-knowledge. Many challenging follow-up activities which could have encouraged the children to question their beliefs about chance were not taken, generally because they were not considered part of the lesson planning or because the student had not realised how long preceding tasks would take.

Unfortunately most students saw the activities that they had planned as the basis for a single lesson (even thought they had to plan four), not as part of an ongoing sequence with potential for development of further mathematical ideas.

For example, EG (name coded) had children consider dice being used in a game of Snakes & Ladders and used questions such as:

Is there one number that is hardest/easiest to get?
How long does it take to get a six?

Both of these questions could have provided some interesting starting points for discussion and further work; neither occurred, and there was no evidence of follow up lessons on this theme. SN also used Snakes & Ladders and asked some particularly imaginative questions:

Are there more snakes than ladders, if so is this fair?
Do you have a lucky number?
Is there a particular number that is easier to roll?
Is it possible to finish the game without going up/down a snake or ladder?

Some of these questions could have provided a basis for very useful investigations. However the answers were summarily dealt with and the opportunity for a challenging investigation lost.

Some students did not consider the mathematics of probability. LI played a game by drawing multi-coloured marbles from an urn with no replacement, it was intended that this game would last for a 20 minute lesson. Her class consisted of 6-8 year old children and LI had not analysed the difficulty of the mathematics involved in non-replacement. After each draw the probability of the remaining colour changes, presenting the participants with a different probability situation. She had not experimented before the lesson, and, because she had found the suggestion in a resource book, accepted it without question. This lack of preparation is of course not limited to teaching probability, but LI's lesson was disastrous, with the game being over in a few minutes and she was left with no idea what to do next.

It is not just the curriculum documents that create such problems. A common reference for primary teachers Griffiths & Clyne (1988) uses children's story books as a way of integrating mathematics and the language curriculum for primary teachers. From one story, 'Phoebe And The Hot Water Bottles', a suggested activity is that the children should draw graphs of the presents they get when they have been very good. The graph illustrated for this activity shows a class graph of their pets made by some children in one of the trial schools. There is no information other than the heading. The scale used is unclear and appears to be inaccurate. This type of reference only serves to confuse students more.

Probable/improbable events

In *Mathematics - a Curriculum Profile*° (p. 62) is the suggestion that children 'order a few easily understood situations from least likely to most likely, e.g. 'my teacher will come to school with green hair'. Ortiz de Haro (1996, pp. 60 - 62) points out that such activities cannot be repeated (as can the tossing of a coin or die) and are therefore not caused by randomness. This is a matter for concern because such activities are suggested in a majority of teacher references.

Using the *Profiles*° led some students to compile lists for discussion with the class of probable or improbable events, and frequent examples of the 'I will come to school tomorrow with blue/ green/ purple hair' *genre* were observed. In using this type of activity students suggested as many patently impossible situations as possible:

Tomorrow will be Christmas day;
Martians will land on the school roof;
If I roll a dice the number will be forty-seven;

it is equally important for students to consider situations that are likely, possible, or certain. These are equally realistic outcomes of a random event and must also be presented for consideration and understanding by children. It is important for example, that children are clear about the difference between, likely, possible and certain. Questions like, 'if we

rank events on a line with 'impossible' at one end and 'certain' at the other, where would events that are likely, possible or certain fit'? Questions like this need to be presented, the need to categorise random events in this way was not considered.

SN who integrated her planned mathematics lesson with a topic on 'weather' examined weather reports from the newspapers and television. Weather reports from the previous day were examined by the children in the class who were asked questions like, 'How did they [weather forecasters] know it would not be hot today?' and were then asked to predict the chance that 'it will be hot tomorrow and we will go swimming'. This lesson was taken in the middle of an Australian winter, but the illogicality of the questions used was lost on this student. She considered that asking children to *predict* was what probability was about and therefore considered the lesson and the questions to be good.

Dice

Dice as random generators are preferred by a majority of teachers and students: dice are familiar and comfortable and students feel that here, at least, is an object with which they can feel in control. It may be seen that here that there are elements of language and prediction involved, factors they have already identified as being important in teaching probability.

Many students when justifying lessons with dice as the basis, quoted the Overview statement of Chance & data in Band A, (AEC p. 165) which begins with the statement:

> During the early primary years children should carry out experiments which involve chance processes (e.g., toss a die) and examine the outcomes; that is, they should try an experiment and note the 'results'.

While some of the settings for lessons chosen were imaginative, the questions and experiences offered to the children were limited and often lifted straight from references.

Activities that involved tossing dice and recording the results were frequently used, without any follow up activity or very much questioning. A show of hands to indicate who got which number was used by two different students. In both cases there was no indication as to how the resulting data would be used, and the next lesson moved away from using dice altogether and introduced another, unrelated lesson.

Games like Snakes and Ladders and Lotto were frequently used. In a study of young children's perception of random generators, Truran (1994) observed that 'the chance aspect of probability is seen as being related to games, and the use of 6 sided die, and this is the [teaching] approach taken in many classrooms'.

LJ wished members of her Year 1 & 2 class to 'investigate the meaning of chance and outcomes of one-chance experiments'. They were to do this by 'playing a game and investigating the outcomes of rolling a dice students will investigate the meaning of chance'[sic]. How this was to be done was not made clear, nor was LJ sure how to tell when the children had understood the meaning of chance. KF asked her class members aged 5 - 8 years to 'predict the outcomes' of tosses of an individual die. There was no indication of a follow up lesson or even discussions about the results of the tosses.

Sometimes dice were used as a basis for a data activity. The task that DH set asked that 'the students individually will roll a dice ten times and communicate the results in a graph shown by me'. SN asked children in her class to roll 2 six-sided dice and to record the results.

My suggestion that there might be other random generators or that others might be constructed were met with amazement. Students' own personal experiences are often limited to the use of a single, six faced die there comments often indicated that the use of a die would make the concept of chance clear to the children. OB had his class of year 6 students tossing pairs of dice; he was confident that 'by the end of this activity students should begin to have a healthy scepticism for situations involving probability'. It would seem that students consider that manipulating the objects themselves transmits concepts of chance.OB also considered that this activity would enable students to identify fair and unfair situations.

Data

Students were encouraged to concentrate on either chance or data and 7 chose to concentrate on data. It seems from this study that data is viewed with as much confusion and reliance on references as Chance. The most common confusion facing these students was what data collection is, how the information should be recorded and why you do it.

EL had considered The *Profiles* as a source for planning a series of lessons on Traffic for 11 year olds. Lesson 1 presented children with two similar, but not identical pictures of a freeway, and the children were asked to 'find the eight differences that exist between two pictures' which they were then to go on and graph. While this lesson may well have provided an example of collection of data, EL had not thought about how this data could be interpreted. EL's response to the children's confusion at this part of the lesson was his first indication that the question was inappropriate. He finished the lesson at this point, telling the children that 'they would do the graph tomorrow'. On the following day a new task was presented to the children and the issue as far as DK was concerned was over.

Another of EL's lessons involved children using a street directory to 'find the quickest route based on the information on a map like distances, speed zones, heavy traffic areas and stop lights'. EL explained:

> Irrelevant data will also be included so that students must analyse the data and evaluate what is required. Children will also use S=D/T formula for time calculations. Examples will be given.

It is difficult to link these activities to the concept of data. They eventually spanned 5 lessons and all proved too difficult for the children, EL was devastated as his attempt to 'teach data' fell into disarray. The worrying thing about EL's plans was that they were written in close collaboration with his supervising teacher who had obviously approved them for use with the class. This teacher did not provide EL with any real support at this time and DK was very angry about this when we talked about these lessons later.

Equally worrying were the lessons devised by WM. The aim of one of her lessons with 8 year olds was that the children 'represent, interpret and report on data, and answer questions posed by themselves and others'. (AEC, 1991 p. 172). In order to do this she set a task for children working in groups of four, with each child working from a different supermarket price sheet. They were given a list of ten products which they were to find on their individual sheets and to then graph their results using a column graph. It was intended that at the end of this lesson:

> Children would discuss brand names that they bought, whether they exceeded their budget and how easy or difficult they found the exercise. Children discover which supermarket overall is the cheapest.

It was not made clear how WM thought children would graph the information that they were asked to collect, or the purpose of such an exercise. WM could not remember how this lesson had progressed or what her teacher had said about it but believed that it had been a good lesson.

LI was working with 7-8 year olds and set them a task which required them to 'toss this die ten times and communicate the results on a graph which was shown by me'. LI modelled the graph, there was no opportunity for the children to construct a graph of their own design. For LI creating the graph was the objective, with no reference to the relationship between the shape of the graph and the outcome of the ten tosses.

Conclusion

Azcárate Goded (1996) has carried out a study into the understanding of chance and probability concepts held by prospective primary school teachers in Spain. Her findings, listed below, identified four relevant concepts held by the group. Evidence of a similar devaluation, described in this paper is listed in italics.

Very few students displayed a clear understanding of the characteristics of random events.
Very students had the mathematical background or skill to clearly understand what is involved in the teaching of stochatics. It does not help them very much if they consult some of the curriculum references.
Most reason from causal pre-suppositions which they use to justify the chance nature of phenomena, or even their deterministic character.
Most approached their teaching from a position of half-understood truths and indicated that the presuppositions from which regard stochastics as a topic has no real definition;
Personal experience determined their ideas and their beliefs rather than the phenomenological outcomes.
There was little evidence from students notes that personal experience determined their ideas and their beliefs, unfortunately I did not see any of these lessons given and did not have an opportunity to discuss this point with the students.
Levels of comprehension and use of normative models are minimal and, usually, restricted to the context of games. This presents great difficulty when interpreting probabilistic information arising naturally , particularly frequencial data, and many of their arguments seem to be based on their own deterministic thinking.
Models that were presented were generally dice based games which were used extensively by the students in this study 10 students chose this format for at least one lesson.

Further Comments

A significant concern for me was that although students were asked to plan four lessons there was little evidence of consideration of a need for development of children's ideas. The majority of students planned four individual, unrelated lessons.

Chance & data both involve complex ideas that need to be seen as a related, integrated whole, both with mathematics and the rest of the school curriculum. The common element of the material discussed in this paper appears to be the total confusion the students had about defining teaching outcomes of, and mathematics involved in this topic. They were enthusiastic about beginning their practicum, had met and liked the children that they would teach and wanted to do their best to provide them with stimulating, interesting, useful lessons. Presenting stochastics ideas to children is complex; and even the most enthusiastic teaching studies student appeared to find the task immensely difficult.

'Probability is a wet Friday activity. It's a nice thing to do when its been raining all day and the children are restless. Bring out the dice and coins and let them play with them, learning will surely follow. Data can be covered in any project or activity'. These comments, and others like them have been made frequently by practicing teachers when discussing with me 'what is Chance & data?' at in-service courses in primary schools in S.A.

The fact that the majority of these lessons were planned with supervising teachers who believed that they were appropriate, both in terms of suitability for the class and statistical accuracy, indicates that many classroom teachers do not understand concepts of Chance & data themselves. Lecturers who are not maths specialists supervised some of these lessons found the majority of students had not come to terms with the concepts of Chance & data and spoke of general confusion about the topic, lessons that had no clear definition or conclusion, and children unsure of what the lessons were about. While these same observations, particularly the last two, were made to a lesser extent about lessons based on other mathematics topics there were not the same reports of general confusion.

We need to re-think the time and effort put into both pre-service, and in-service courses for practising teachers whose own experiences in this area appear to be lacking. If we are to overcome teaching students' confidence and lack of knowledge we must have classroom teachers who are confident and in control of this important topic. We need to consider examples of good questions to begin a discussion; appropriate and challenging question sequences and analyses of children's responses to questions. How this can be done given the short time available and the other demands of mathematics topics within the course is a mystery. In my own institution I have re-structured each of the subjects so

that in each year the students consider in depth, two Strands of the *National Statement.* This may limit the course, but the advantage is that it allows for a more in depth approach and gives more time to consider the difficulties and confusion related to learning and teaching some topics, particularly Chance & data. I intend to try this approach for 2 years to see if there are more positive teaching outcomes for students. The observation and quotes from students throughout this paper are not made to devalue them or their work. They were used to demonbstrate the confusion and difficulty that pre-service students experience in planning and teaching stochastics lessons.

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