TEACHING STATISTICS AT THE PRIMARY LEVEL: IDENTIFYING OBSTACLES AND CHALLENGES IN TEACHER PREPARATION FROM LOOKING AT TEACHING

Aisling Leavy
Mary Immaculate College, University of Limerick, Ireland
aisling.leavy@mic.ul.ie

Preparing preservice primary teachers to teach statistics is a complex endeavor. The challenge is to enrich content knowledge, advance pedagogical understandings, and develop the types of thinking and dispositions necessary to support instruction. This paper reports on two studies of 51 final year preservice primary teachers engaged in 'lesson study'. Working with preservice teachers provided unique insights into the types of understandings they draw on and the difficulties they encounter when teaching and reflecting on design lessons. The study revealed that for participants the teaching of statistics is perceived as straightforward, content knowledge understandings tend to be weak and limited to procedures, and experiences of investigation is limited. Experiences planning lessons and teaching in classrooms, however, present opportunities for the development of content understandings and for developing sophisticated perspectives on data.

INTRODUCTION

Statistical literacy is a critical skill required of citizens in quantitative-rich and information-laden societies. As recently as two decades ago, however, statistics education in elementary and middle schools was identified as inadequate and instruction focused on the procedural and computational aspects of statistics rather than on developing conceptual understanding (Garfield & Ahlgren, 1988; Shaughnessy, 1992). The traditional emphasis on skills development resulted in many students not being able to think or reason statistically and led to the call for statistics education to focus on statistical thinking and reasoning (Moore, 1998). Since then, there have been a number of attempts to reform the teaching of statistics and provide greater emphasis on statistical thinking, reasoning, and literacy. Suggestions include, but are not limited to, focusing instruction more on data and less on theory, building in experiences of real data and real-world problems into statistics curricula, increasing the amount of active learning, and increasing access to the range of different insights afforded by technology.

IDENTIFYING THE KNOWLEDGE NEEDED TO TEACH STATISTICS

Changes in statistics curricula have placed demands on the preparation of preservice teachers. One challenge is identification of the types of knowledge needed to teach statistics. Effort has been expended on identifying teacher characteristics that are indicators of good mathematics teaching. Attention has focused on teacher knowledge of mathematics, commonly known as *mathematical content knowledge* or subject matter knowledge (Shulman, 1986). At a certain stage, however, the relationship between teacher mathematical knowledge and instruction levels out and simply increasing the number of mathematics (or in this case statistics) classes taken does not bring about improvements in instruction (Borko et al., 1992). The issue of mathematical content knowledge in statistics is particularly relevant for teachers of statistics. Many teachers of statistics, at the primary and secondary level, have expertise in mathematics but may not have adequate exposure to statistics. Hence, the development of statistical content knowledge is critical for teachers of statistics.

Another area of research focuses on how teachers use mathematical knowledge to carry out the tasks of teaching. This emphasis on *substantive knowledge of the subject* consists of understanding the information, ideas and concepts related to the content that is the focus of instruction. Ball (1988) refers to this type of knowledge as *knowledge of mathematics*, knowledge described by Ma (1999) as *profound understanding of fundamental mathematics*. Arising from research on teacher's subject matter knowledge and its role in teaching and the interplay between mathematics and pedagogy, Ball has developed a theory of *mathematical knowledge for teaching (MKT)* (Ball, 1999; Hill, Rowan & Ball, 2005). This type of knowledge includes both mathematical knowledge common to those working in diverse professions and the mathematical knowledge that is specialized to teaching. This knowledge can be viewed as the type of knowledge needed to carry

out the 'work of mathematics' (Hill, Rowan & Ball, 2005, p. 373) and involves explanations of concepts and terms, providing examples of concepts and algorithms, selecting and constructing representations, and interpreting and evaluating student's responses and solutions etc. It is this type of knowledge that is frequently developed and addressed in pedagogy courses, and in the case of statistics education, targets exposure to the models, representations, and processes central to statistical thinking and reasoning.

The teaching of statistics, as compared to mathematics, has additional considerations when taking into account the types of knowledge needed for teaching. The knowledge needed to carry out the 'work of statistics' extends beyond concepts, terms, and representations. Statistics did not originate within mathematics and as a result many of the core statistical ideas are not mathematical in nature. David Moore (former president of the American Statistical Association) refers to the growing recognition that statistics while closely related to mathematics is a distinct discipline "statistics, while it is a mathematical science, is not a subfield of mathematics" (Moore, 2004, p. x). As compared to mathematics, when dealing with statistics there may not always be a right answer, data is messy, and context is important. For teachers, developing the habits of mind associated with statistical thinking is as important as developing the knowledge and understandings that underpin statistical activity. These habits of mind are developed by engagement in exploratory data analysis activities involving the collection, exploration, and interrogation of data. However, within teacher education contexts, many preservice teachers have not taken courses in applied statistics nor engaged as learners in the processes of statistical investigations. As a result of the relatively impoverished experiences of some preservice teachers, identifying, assessing, and developing these types of knowledge and understandings can be a challenging task.

THE PROBLEM

The field of statistics education is still in its infancy. However, the recent proliferation of research in the field has lead to significant gains in understanding specific elements of statistical thinking, for example conceptions of central tendency and variability. Attention has also been placed on broader aspects of statistics such as distribution, in addition to the the development of frameworks of statistical thinking and empirical inquiry (Wild & Pfannkuch, 1999). Significant advances have also been made in the development of cognitive models of children's statistical thinking (see the work of Jones et al., 2000). Advances have also been made in teacher education in identification of specific content knowledge needs (Canada, 2008; Chick & Pierce, 2008; Groth & Bergner, 2006; Leavy & O'Loughlin, 2006) arising from insights generated from work examining engagement in statistical investigations (Burgess, 2008; Leavy, 2006) and studies examining teaching of statistics in classrooms (Burgess, 2008; Heaton & Mickelson, 2002; Makar & Rubin, 2007). While advances have been made in the development of understandings of teacher content knowledge, teaching statistics requires more than content knowledge. We still know little of the obstacles faced by practising and early career primary teachers when teaching statistics and of the particular knowledge demands that arise when teaching statistics. Development of these understandings is critical to feedback into teacher education and inservice courses and inform the provision of experiences that serve to prepare teachers for the demands of classroom teaching.

The present paper reveals insights into the knowledge that preservice teachers draw on when developing lessons around key statistical concepts and also sheds light on the decision making processes used to identify and develop pedagogical approaches to illuminate these statistical concepts.

METHOD

Participants

Participants were 51 preservice primary teachers enrolled in mathematics education as a cognate area of study; 26 were enrolled in Spring 2008 and the remainder in Spring 2009. Participants were in their final semester of their undergraduate program and had completed all required mathematics education courses (three semesters) and all teaching placement requirements (at junior, middle and senior elementary grades). Four were male and the mean age was 20.27

years. Eighteen were studying mathematics to degree level and the remainder studying alternative liberal arts subjects.

Data Collection and Analysis

Participants were observed as they engaged in *lesson study* (Lewis & Tsuchida, 1998; Stigler & Hiebert, 1999) in an effort to examine the kinds of knowledge they draw upon when designing and teaching statistics lessons. Participants worked in lesson study groups consisting of 5 people per group, each of which focused on teaching a specific statistical concept/idea. Key concepts were identified from an analysis of international curricula and policy documents.

The first phase, weeks 1-3, was dedicated to introducing lesson study and revisiting aspects of data handling in the primary curriculum. Participants completed a concept map of data handling; analysis of concept maps resulted in two class sessions being dedicated to reviewing aspects of data handling in the primary school with particular emphasis placed on developing an understanding of the enquiry cycle in statistical investigations. The second phase, weeks 4-10, involved conducting the lesson study. The researcher moved between roles of participant observer and mentor, depending on the needs of groups. The lesson format adhered to guidelines put forward by Ertle, Chokshi, & Fernandez (2001). The final phase, weeks 11-12, involved each group reporting on the lesson study. This centered on three activities: a focus group interview, presentation of an individual reflective paper, and in-class presentations of group outcomes.

Data were analyzed utilizing strategies synonymous with grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1998), which included concurrent data collection and analysis, a two-part process for coding data, utilizing comparative methods, memo writing, refining emerging theoretical ideas by sampling, and integrating a theoretical framework. Throughout the process of data analysis, action codes were created and the constant comparative method employed. Through a process of re-visiting the data in an effort to find support for or evidence against the emergent themes, the final categories were established. To ascertain validity of each category, three or more different data sources were triangulated to affirm presence of the category. These sources included information gleaned from interviews, observations, video tapes, audio tapes, participants' written work, group logs, field notes, and lesson plans. Once topic saturation was reached, the researcher met one last time with five of the lesson study groups and used a tailored in-depth interview model to verify that no additional themes had been overlooked. Arising from the categorization of thematic similarities and differences across the data sources, an account emerged illustrating preservice teacher's knowledge and understandings of the teaching of data and illuminating situational variables which impact the teaching of data handling in primary classrooms.

RESULTS

Analysis of data arising from lesson study identified a number of themes relating to the knowledge needed to teach statistics at the primary level. Some of the themes support previous findings relating to content knowledge difficulties, others however provide new insights into how preservice teachers reason about the teaching of statistics.

The teaching of statistics is perceived as straightforward

Participants were unaware of the types of knowledge and understandings required to teach data-handling and possessed a false sense of security regarding their preparedness to teach data handling concepts. The discipline of statistics was perceived as little more than the application of a defined number of procedures on a predefined set of data. Participants believed that they possessed sufficient understanding of these procedures and consequently they experienced no conflict or discomfort in terms of their readiness to teach statistics.

Understandings of central tendency were superficial and limited to procedures

There was strong evidence of *instrumental understanding of statistical concepts* (Skemp, 1977) as demonstrated in the ability to apply procedures which generate measures of central tendency and implement the correct procedures for constructing graphical representations. Initial ideas for lesson plans focused on identification of methods and 'tricks' to demonstrate procedures. Confusion existed about individual measures of central tendency and their *relation* to each other. In particular,

there was evidence across groups of the tendency to underestimate the complexity of the measures and a lack of awareness of the properties of individual measures. For example, participants were unable to provide a rationale for why one measure of central tendency may be preferable to another when representing a data set that had outliers. Problems understanding issues relating to *data type* (categorical/quantitative data) were pervasive throughout the study. Appreciation of the impact of data type on selection of measures and graphs was limited. There was poor *relational understanding* of the ways in which statistical concepts, measures, and representations are structured and related to each other. When planning the statistical investigations, *knowing both what to do and why* within the framework of the investigative cycle posed difficulties. Participants were not entirely sure of the rationale behind using specific measures/graphs and found it difficult to coordinate their statistical understandings within the framework of investigative cycle.

Designing and teaching lessons in real classrooms challenged traditional conceptions of what it means to teach data

- *What makes a good data unit?* Prior to the study participants had never had the opportunity to reflect on what constituted a 'good' data investigation. Data handling, it seemed, had meant primarily the construction of graphs and asking questions involving graphical comprehension, and the calculation of measures of central tendency and variability. Engaging in designing lessons revealed the importance of designing coherent units based on statistical investigations within which analysis of data served a functional and integrated role.
- *Reasoning and making sense beats calculating any day!* It was the act of designing and teaching lessons for real classrooms that lead preservice teachers to question the rationale behind traditional approaches to teaching data which focus primarily on the selection and application of correct procedures to calculate measures of central tendency. It was not until groups struggled with providing a rationale to children for the selection of specific measures of central tendency that conceptions of measures of central tendency and variability moved from 'things you do to data' to 'important analytical tools for examining data'.

     'I was quite confident at the start that I knew exactly what was involved when it came to working out statistics. I knew how to find the mean, range, mode, median and what an outlier was. What I didn't realize is that knowing the <u>why</u> of calculating these is just as important as knowing the <u>how.</u> … It is of upmost importance that we know why we are finding the mean, median and mode etc. and almost useless if we can just use equations that we have learned off to work these out without any reason or basis for it. This was an aspect we had trouble with in designing the first lesson place as we were just asking the pupils to work out the statistics of the data rather than giving them a reason as to why they should work it out.'   (SR, group 5)

- *The tension between designing driving questions and the data they generate:* A difficulty arose when groups were focusing on designing driving questions to motivate statistical investigations. Participants did not seem cognizant of the critical role played by data type in supporting the development of statistical reasoning. The initial investigations proposed by the groups all generated discrete data. Discrete data, as compared to continuous data, limit the types of analyses that could be carried out on the data, and the degree to which inferences could be made. Participants struggled with the tension between designing investigations which would be interesting and relevant to children while simultaneously generating data whose structure was supportive of the types of reasoning critical to informal inference.
- *Why spend valuable time on constructing graphs when you can be analyzing and interpreting?* Observations of the sophisticated approaches children used when analyzing and interpreting data lead preservice teachers to question the common practice of allocating large periods of time to the construction of graphs.
     'When I get my own class, I will ensure that the emphasis of the lesson is placed on interpreting the data rather than the collection of and the representation of the data. Although these methods need to be taught well, without the interpretation of the data, the data itself is worthless'   (EK group1)
- *Context matters a lot!* Participants reflected at length about the nature of the contexts that stimulate statistical activity. This reflection on contexts was further emphasized during in-class

presentations where groups shared the outcomes of their lesson study projects and provided insights for each other into how different contexts for investigations worked.

> 'I now realize that the lesson context should always be researched in great detail beforehand. It has to be fact. This is especially true with the older classes. There are holes to be poked in made up stories and data and they will find them. Plus a real life situation will be far more interesting than a made up one and will hold their attention for far longer.'
>
> (RLS group 2)

CONCLUSION

The results of this study highlight that experiences of statistics at second and third level do little to support, and in some cases present obstacles to, preservice teachers in teaching statistics in pedagogically sound and appropriate ways. Firstly, prior experiences of statistics did not provide the necessary exposure to statistical concepts and ideas that are central to primary level statistics. For example, participants had few experiences engaging in the process of statistical investigation (cf. Wild & Pfannkuch, 1999) that are central to activity at primary level. Moreover, experiences of statistics did not contribute to the development of adequate conceptual knowledge necessary to support the teaching of statistics at the primary level. Experiences seemed limited to the reproduction of memorised facts, the application of rules and use of algorithms learned during instruction, and consequently contributed to the development of procedural knowledge devoid of conceptual underpinnings. Surprisingly, the knowledge gained from undergraduate courses in statistics did not produce the kinds of understandings necessary to support the teaching of primary level statistics. Participants in the study who were studying mathematics at undergraduate level, and who had recently completed a module in probability and statistics, did not diverge from their peers in terms of statistical understanding. During the lesson study group interviews and meetings, mathematics majors were not observed making contributions related to statistical content.

In conclusion, this study provides unique insights into obstacles preservice teachers face when planning for and teaching data lessons in live classrooms. It reveals content and pedagogical content knowledge difficulties in addition to aspects of statistical understanding that relate directly to designing and teaching statistics using statistical investigations. The study reveals the complexity of teaching statistics for early career teachers and highlights that intricate, complex and interconnected landscape of teaching statistics and the concomitant implications for teacher educators of developing knowledge for teaching statistics. The results of this study indicate that innovation in the teaching of statistics is a realistic goal. Engaging in lesson study challenged traditional conceptions of what it means to teach statistics. The provision of intensive support for planning and teaching statistics, and the provision of feedback on that teaching, resulted in instances of classroom teaching that were exemplary in terms of the provision of learning experiences and the development of children's statistical understandings.

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