TEACHING PRIMARY TEACHERS TO TEACH STATISTICAL INQUIRY: THE UNIQUENESS OF INITIAL EXPERIENCES

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Experience with statistical inquiry has been advocated in statistics education as vital for learners' understandings of statistical processes. Research has suggested, however, that practices at the school level have focused almost solely on graphs and procedures. While important, these skills do not develop learners' abilities to cope with the decisions that arise in the face of uncertainties and ambiguities that accompany statistical investigations. A longitudinal study in Australia researched experienced primary teachers' evolving experiences in teaching statistical inquiry. This paper will report on the uniqueness of teachers' early experiences in teaching statistical inquiry, an issue that emerged in the first three years of the study. Critical skills that teachers need to develop to teach statistical investigations that are often neglected in teacher professional development are discussed, including implications for research and teacher education.

INTRODUCTION AND LITERATURE

Statistical inquiry is a process of addressing ill-structured problems through the investigative cycle (PPDAC) put forth by Wild and Pfannkuch (1999). Ill-structured problems involve context-rich questions with ambiguities in the problem statement or structure which require negotiation to define. For example, students could address the question, "Do students at our school eat a healthy lunch?" Although this appears to be fairly straightforward, both the problem statement and structure needed to address the problem require further definition before investigation. For example, what constitutes "healthy" food can be considered contentious: Are cheese, juice or muesli/granola bars categorised as healthy or unhealthy? In addition, decisions need to be made about what information needs to be obtained, how it will be obtained (e.g., sampling and surveying designs), the analysis of the data and what will be communicated in responding to the question.

Many countries now suggest or mandate that classrooms engage in statistical inquiry, however research has suggested that the practices too often focus the majority of time on the details of computation and graphs (Sorto, 2006; Pfannkuch, Budgett, Parsonage & Horring, 2004). The initial processes of statistical investigations—the PP in the PPDAC cycle—are frequently neglected (Arnold, 2008; Fielding-Wells, 2010). As Shaughnessy (2007) articulated so well:

> Most of the current statistics education in the United States places a heavy emphasis on the DAC parts of the Investigative cycle, but precious little time is devoted in classrooms to the PP parts. If students are given only prepackaged statistics problems, in which the tough decisions of problem formulation, design and data production have already been made for them, they will encounter an impoverished, three-phase investigative cycle and will be ill-equipped to deal with statistics problems in their early formation stages (p. 963).

In suggesting or mandating that schools incorporate more of the early stages of investigations, assumptions are made that either teachers are already confident in teaching statistics through inquiry or that developing teachers' expertise is a simple matter of providing training. Little is known about how teachers themselves develop the expertise required to guide students effectively in teaching statistical inquiry. Many studies which engage students in statistical inquiry are either taught by the researcher (or in collaboration with the researcher) or are small scale case studies of isolated insight. More needs to be understood broadly about teachers' experiences in learning to teach inquiry if there is realistic hope of shifting the primary focus in school statistics from graphs and computations to inferential reasoning through complex inquiry.

Critiques of inquiry often cite the learning paradox, where it is argued that students cannot construct knowledge that they do not already have (see Simon, 1995, for further discussion of this point). Likewise, overly focusing on "activity-based" learning in absence of significant content is

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another common criticism of inquiry that has been made: "If, for example, students spend their time [in science] making Jell-O moulds of dinosaurs and everyone calls the result 'hands-on science', no improvement over the lecture system will have been realized" (Powell, 1994, p. 24). Inquiry and similar constructivist approaches are distinctly different than discovery learning (Confrey, 1991) and require significant support and content knowledge from teachers. This makes it one of the most challenging approaches to teaching. Critics of inquiry often assume an 'all inquiry' or 'no inquiry' dichotomy or embrace epistemologies that presume knowledge can be developed and deepened only through direct teaching.

Inquiry itself in other content areas (especially science) has suggested that initial experiences teaching inquiry can be highly stressful for the teacher. The negotiation of multiple uncertainties and the lesson not going as planned can be frustrating (Anderson, 2002) and require additional support (Hills, 2007; Marx et al., 1994). Studies of educational innovation have often suggested that in trying new pedagogies, teachers often experience an 'implementation dip' which can further add to this frustration (Pendergast et al., 2005; Fullan, 2008). If this frustration is high enough, then teachers can reject inquiry as a pedagogy altogether before they've given themselves time to adapt to the new demands (Krajcik et al., 1998). This is of great concern if teachers are convinced that inquiry 'doesn't work' as an approach, based on their early experiences. Furthermore, if they lack confidence in their content knowledge, this can also affect their ability to take risks and deepen student learning (Arnold, 2008).

This paper reports on one aspect of an ongoing longitudinal study (2006-2012) which examines the processes of primary teachers' development of inquiry-based practices in mathematics and statistics. In particular, the paper focuses on the uniqueness of teachers' initial experiences with inquiry and the incongruity between their recognition of the benefits and ideals of inquiry and the challenges they initially encountered in implementing it. The paper draws on group and individual interviews conducted with primary school teachers before and after their first experience teaching mathematical or statistical inquiry, including classroom observations of their teaching. The paper provides suggestions for assisting teachers in adopting inquiry-based practices, as well as implications for teaching and research.

METHODOLOGY

Design and setting

The aspect of the study reported in this paper involved 23 primary school teachers at two schools in Australia from 2006-2008; Four teachers began in 2006 and this was expanded in 2007/2008 to twenty teachers (including most of the initial four teachers). The project is part of a longitudinal Design Study (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003), where the focus is on understanding and supporting teachers' development as they transition to adopting inquiry-based practices (see also Makar & Fielding-Wells, in press; Makar, 2007). The first two years of the study focused on statistical inquiry specifically; this focus was broadened later to incorporate topics in mathematics as well. Teachers engaged in professional learning seminars throughout the project (3-4 days per year) and were expected to teach 3-4 inquiry-based units per year. Classroom lessons were observed to provide common understandings and gain insights into the teachers' experiences.

Data collection and analysis

This paper reports on the semi-structured interviews conducted in the initial professional development seminars (group) as well as interviews (individual) which followed teachers' initial set of inquiry lessons. In these interviews, teachers were asked general questions about their experiences in teaching inquiry, including challenges encountered and opportunities for learning that arose (or were anticipated) for both themselves and their students. Responses were probed to encourage teachers to elaborate on their ideas. Audio-taped individual interviews were transcribed and subjected to open coding to seek categories of teachers responses. These categories were collapsed into themes and sub-themes to seek better understanding of the patterns that emerged. Excerpts were identified from the individual and group interviews to exemplify and illustrate themes in the teachers' own words to better communicate their experiences.

UNIQUENESS OF INITIAL EXPERIENCE

During the initial teacher workshops (before their first teaching episodes), teachers talked about the benefits of inquiry and articulated positive, almost romantic, notions of what it would mean for their students to learn statistics through inquiry:

Josh: I think they're going to be immersed so much.
Natasha: I think it gives them more control over what they're learning … [to] decide what kind of graph or how they even want to represent the data, … and then justifying their original hypotheses.
Carla: When they have their own data they can think 'oh, this might be the best way to display it', you know, when they're working with their own facts.
Kaye: I think the children will benefit greatly from really analyzing data because … well, just being able to take something and really get the depth of talk.

In addition, they expressed some concern about how they could teach their students to work collaboratively. This concern was reinforced in observations and in individual interviews conducted with the teachers after their first set of lessons. On one hand, they were excited about their students' engagement in the activities and still maintained a positive attitude towards the ideals of inquiry. However, at the same time, they were frustrated that their lessons often didn't go as planned. Logistical challenges they encountered further dampened their own enthusiasm for inquiry and they questioned its viability as a teaching approach. Several key themes emerged from analysis of these interviews. Commonly, the teachers were:

- Enthusiastic about student engagement
- Positive about the benefits of inquiry
- Disappointed (including self-blame) when things did not go to plan
- Concerned about classroom management (e.g., how to develop students' collaboration skills, deal with noise, cope with behaviour issues)
- Apprehensive about finding a balance between teacher and student control/independence
- Uncertain about what the inquiry process should look like in mathematics and statistics
- Worried about the extent of their own content knowledge

Comments like the following were common:

Natasha: There was one day I could have thrown my hands up and said 'I'm not doing this' but I could see that the children were enjoying it. … It was exciting for me as well as for the children, just to see where they were going to go with it and what they were going to do and just see them getting so involved.

Lachlan: Yeah, well that's, and I'm just thinking to myself: well, what is the average really? Like, to put it in laymen's terms, I probably couldn't say: well, an average is, it's an average, isn't it? So, maybe it was me; that I had to have a better knowledge of the mathematical concepts to sort of lead them better. … I'm not sure. Yeah.

Table 1 summarises the number of teachers who expressed these issues in the interviews, grouped according to themes and subthemes that arose in the analysis. Note that categories were often overlapping, so totals are not simply accumulated.

The majority of teachers talked about particular issues in their interviews—difficulties in negotiating processes unique to inquiry, logistics of managing classroom behaviour, support and curricular pressures, and concerns about their new demands on their understanding of content. The common pattern of these issues being raised implies that they were systematic concerns. A key element of teachers' initial experiences with inquiry was the disconnect between these positive, sometimes idealised initial perceptions and experiences of statistical inquiry (e.g., the anticipated benefits of inquiry, excitement over initial student engagement) and the challenges associated with implementing inquiry in the classroom (e.g., classroom management, managing disappointment

when things did not go as expected). This disconnect has been found in other studies of teacher education (Pendergast, 2002). Although the teachers had positive regard for the benefits of inquiry, there is concern that without ongoing support, teachers may decide that statistical inquiry 'doesn't work' when practicalities are challenging and abandon the idea of engaging with inquiry–not just in the short term, but potentially in future opportunities as well.

Table 1. Categories of topics discussed by the teachers in interviews

Category	Number of teachers (n=23)
Positive disposition towards inquiry	22
Student engagement	21
Acknowledging benefits of inquiry	20
Managing the inquiry process	23
Challenging for students	19
Disappointment/blame	18
Unanticipated directions	15
Envisioning Inquiry	13
Practicalities of making inquiry work	21
Classroom management	18
Curriculum/time pressures	17
Balance of teacher & student control	13
Content knowledge concerns	7

DISCUSSION

Teachers' early experiences with statistical inquiry created some discord between the ideals of inquiry and their actual experiences. On one hand, they were in agreement about the benefits and potentials of inquiry for deepening students' understanding of statistics. However, their initial experiences created unanticipated problems that left them feeling uncertain about its viability as a teaching approach. The teachers' interviews provided evidence that their frustrations and challenges often stemmed from the three key elements below. To support teachers through their initial experiences, a number of recommendations are made to counter these frustrations. These elements are not distinct from one another but are interrelated and overlapping.

Difficulty with the uncertainties of inquiry

Teachers expressed concerns about the challenges of being able to envision inquiry processes in a mathematics classroom, including concerns about whether students could cope with the additional challenge of open-ended problems, selecting interesting data-based questions to work on, negotiating unexpected outcomes and directions, changing a mindset about learning processes and managing the complex interactions between abstract content and context. This implies the importance of allowing teachers to engage with inquiry as learners themselves to experience first-hand both the overarching structure of it and so that questioning and support structures can be modelled by the facilitator.

Managing logistics of inquiry

The practicalities of inquiry—including classroom management issues, dealing with curriculum/time pressures and balancing student-teacher control—was one of the most common concerns teachers articulated in their early inquiry teaching experiences. This implies that support must be provided for teachers to develop a culture of inquiry in their classrooms, including explicitly teaching students skills in collaboration, argumentation, and managing project work. They also need support in how to align statistical inquiry with their curriculum (including interdisciplinary work) and find strategies that allow for the additional time needed.

Having a solid content background

A solid foundation of statistical concepts is vital for giving teachers the confidence to manage the uncertainties inevitable in teaching statistics through inquiry. Although teachers did not often discuss their content knowledge concerns directly, a strong statistical grounding is vital to develop students' statistical reasoning and guide them towards deeper understandings. This is critical to avert the chronic focus on calculations and graphs frequently reported in research (see for example, Sorto, 2006; Pfannkuch et al., 2004). Additionally, a stronger content background will enable teachers to better capture opportunities for deepening content, see the connections between students' statistical reasoning and the curricular goals they are aiming to develop, and better manage uncertainties that arise.

CONCLUSION

This study has suggested that the level of frustration in teachers' initial experiences in teaching inquiry is unique. The challenge of conceptually mapping a vision of inquiry into their statistics lessons may be central to this difficulty. For example, most lessons in a mathematics classroom flow fairly in line with teachers' planning. Their experience in teaching mathematics is that problems normally follow a predictable, often linear, solution path. Inquiry, on the other hand can raise new questions, require backtracking, expose ambiguities, uncover uncertainties and move in unanticipated directions which are all difficult to manage when it launches teachers out of their comfort zone and/or is contrary to what they expect.

The implications of this study are broad for our understanding of teachers' initial experiences in teaching statistical inquiry. It implies that greater attention needs to be placed on giving teachers experience with inquiry as learners, providing them with skills to cope with and manage classroom logistics and deepening their content knowledge. In terms of research, the study raises questions about how we might better theorise teachers' experiences teaching inquiry to expand our knowledge of the legitimacy of challenges that teachers face. Likewise, it is important that we not ignore these challenges or presume the goal is to eliminate these challenges, but rather to focus research on how teachers negotiate and use these challenges to build their expertise (see, for example, Makar & Fielding-Wells, in press). For practice, the study highlights the importance of supporting teachers as they engage with inquiry, particularly in the early stages. It further highlights the importance of taking advantage of the curriculum pressure by increasing the shift in emphasis towards statistical reasoning and processes in curriculum. It also serves as a reminder that adoption of inquiry is complex and is not simply a matter of 'training' teachers, but a process that requires significant support over time.

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