A MODEL OF LEARNING TO TEACH STATISTICAL INQUIRY

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Although the inquiry process is a foundational practice in statistics, it is rarely taught in school. This paper introduces a tentative model to describe primary teachers' evolving experiences in learning to teach statistical inquiry.

INTRODUCTION

The process of inquiry is at the heart of statistics (Wild, 1994). Wild and Pfannkuch's (1999) landmark paper on statistical thinking describes four dimensions of statistical thinking used in statistical inquiry of authentic problems: phases of the investigative process (Figure 1), types of thinking used, ongoing and iterative mental questioning (interrogating), and dispositions required. Since that time, little research has extended understanding of statistical inquiry, although researchers have noted the challenges in conducting inquiry in statistics (Makar, 2004; Britz, Emerling, Hare, Hoerl & Shade, 1997), particularly question formation and relating solutions and evidence back to their original problems (Hancock, Kaput, & Goldsmith, 1992). Despite calls for more emphasis on the investigative process (Moore, 1997), the focus in school statistics continues to be on calculations, procedures, and graphs (Sorto, 2006), although some countries have worked to begin to include statistical inquiry in the national curriculum (for example, Davies, 2007 and Ministry of Education, 2007).

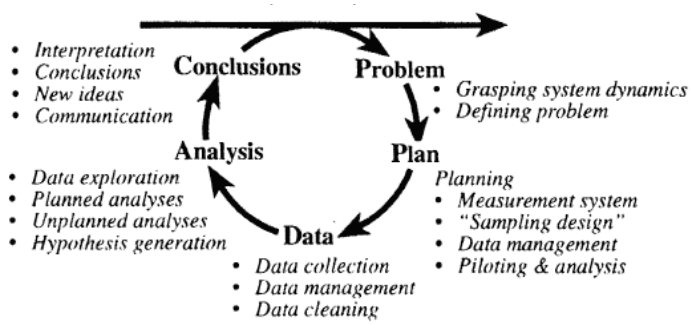

Figure 1. The statistical investigation cycle (Wild & Pfannkuch, 1999)

This paper proposes a tentative model for understanding teachers' changing experiences as they build confidence and expertise in teaching statistical inquiry. Excerpts from interviews and classroom observations of five teachers illustrate key junctures of their focus over time.

BACKGROUND

In inquiry, authentic questions are typically ill-structured: That is, they contain a number of ambiguities that need to be resolved during the inquiry process (Reitman, 1965). Unlike school problems, inquiry with ill-structured problems requires a number of skills, most of which are not typically part of the school curriculum: (a) generating a curiosity about the world that identifies 'I wonder' problems; (b) writing a measurable question that provides insight into these problems; (c) determining relevant, valid, and accessible data; (d) planning and carrying out data collection; (e) checking, cleaning, and organising data; (f) recognising the data's limitations; (g) analysing and interpreting data; (h) articulating findings; (i) seeking explanations; and (j) generating further questions. Rather than be linear and deterministic, the process frequently requires backtracking and revision as new understandings develop and unanticipated problems or opportunities arise. Unfortunately, the focus in schools is almost always on the solution phase, which is typically the least cognitively demanding part of solving ill-structured problems (Reitman, 1965) and the easiest to teach (Britz et al., 1997).

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Inquiry is a well accepted (but not always implemented) process in other school subjects, like science (National Research Council, 2000) and social studies (Gordon, 2000), but it is rarely used in learning statistics. Most educators can envision what scientific inquiry is but often cannot imagine what inquiry entails in a mathematics classroom (where statistics is usually taught). To teach inquiry, teachers need skills often absent in mathematics classrooms:

- ability to cope with ambiguity and uncertainty;
- re-balance between teacher guidance and student independence;
- recognition of opportunities for learning in unexpected outcomes;
- flexible and creative thinking;
- deep understanding of disciplinary content; and
- tolerance for periods of noise and disorganization.

Previous research by the author suggests that teachers' initial experiences with statistical inquiry are uniquely challenging (Makar & Confrey, 2007; Makar, 2004; in press; Confrey, Makar, & Kazak, 2004). This paper reports on a framework from an ongoing study designed to better understand these initial challenges and teachers' evolving experiences as they develop expertise and confidence in teaching mathematical and statistical inquiry over time.

METHOD

The four-year study, which began in 2006, uses a design experiment methodology (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003), where the researcher concurrently investigates and works to improve the study context. The research had the following aims with respect to teaching mathematics and statistics with an inquiry approach:

- to better understand the unique nature of teachers' initial experiences;
- to document support mechanisms that promote confidence and expertise (Makar, in press);
- to identify signature practices of expert teaching (Makar, in press).

Five teachers from Years 3-6 (ages 7-11) from a suburb of a large Australian city participated in the initial phase of the project (2006-2007, the focus of this paper). They had a wide range of experience (0-30 years) and equally diverse backgrounds in statistics. As is common in school research, some teachers were involved throughout the study (Kaye and Naomi), while others left the school (Josh and Carla) and were replaced (Elise). During the project, the teachers received three to four days annually of professional development in which they experienced the inquiry process as learners. In the first eighteen months, the teachers generated and taught nearly twenty inquiry units, some of which were inspired by published units (e.g., Gideon, 1996) and others designed from scratch.

A major aim of the project was to understand the process of learning to teach inquiry from the teachers' perspective. In ongoing interviews, teachers were frequently asked to articulate benefits and challenges they anticipated and experienced in teaching their units and to provide advice to those who may be just starting to teach statistical inquiry. A thematic analysis of their responses was the basis of a preliminary model for understanding teachers' evolving experiences in developing expertise and confidence in learning to teach statistical inquiry.

RESULTS

The model (Figure 2) is intended to depict a developmental evolution with qualitatively different characteristics emerging as the teachers progressed over time. This section describes common qualities exhibited by the teachers in various stages of the model using excerpts from the interviews to illustrate key characteristics emerging in each stage. It should be cautioned that these stages and characteristics are tentative, the sample size quite small (n = 5), and the stages described here are only initial descriptions of this emerging analysis. A second phase of the project (2007-2009 with 20 teachers from Years P-7) is focusing on further elaborating the model and identifying strategic questions for additional research.

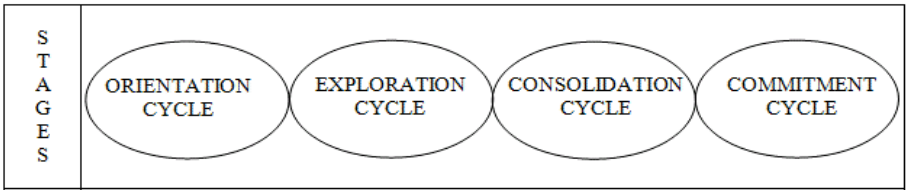

Figure 2. A model of learning to teach statistical inquiry

Orientation cycle

During their initial experiences, the teachers' primary focus was on developing a vision of what statistical inquiry is, coming up with an interesting problem, engaging with structural and cultural aspects of their classroom practice (e.g., group work, eliciting and supporting student independence), and working out curriculum issues.

Josh and Naomi designed a unit that explored trends in winning times in various events at the Commonwealth Games (concurrently held in Australia) and was quite student-driven. In contrast, Kaye and Carla modified a published unit (Gideon, 1996) that investigated unusual characteristics of fellow students (e.g., ability to roll their tongue). Their unit was quite structured, and they explicitly taught students the process of a statistical investigation before they carried out their inquiry. In the first group interview before teaching their units, the teachers discussed their ideas of inquiry. Their comments were positive, almost romanticised at times.

> Josh: *I think they're going to be immersed so much in what we're already doing with the Commonwealth games. …*
> Naomi: *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, … what kind of athletes they want to look at 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 analysing data because … well, just being able to take something and really get the depth of talk.*

Although the teachers recognised the benefits that students would gain with this approach, they seemed to imply that the decision-making processes would be fairly easy for students but recognised that they would find the teaching challenging.

> KM: *What about for you, what's going to be the most challenging aspect?*
> Naomi: *Letting go!*
> Kaye: *Not putting words into their mouth, I suppose, and not having the investigation go the way you think it should go. …*
> Josh: *Just keeping that fine balance between letting them go and keeping, getting something, um, decent done, I think.*
> Naomi: *It's the management. Putting them into different groups and having to work to manage all the groups. … That will be hard.* [Group interview, 14 March 2006]

All four of the teachers found their first unit quite challenging, particularly creating a reasonable balance between structure and student independence. Josh and Naomi ran into curriculum issues as they wrestled with unexpected outcomes that surfaced. Josh's comments were typical of the teachers, blaming himself for not anticipating problems that arose.

> *I guess it taught me to make sure I cross my T's and dot my I's. … I tell you what, if, um, I hadn't have had previous life experience, I probably would have crashed and burned. … The biggest challenge was to make sure that, you know, as I said, everything's ready to go 100%.* [Josh, individual interview, 5 April 2006]

Elise joined the study in the second year (replacing Josh, who transferred to another

school). She and I co-taught a short inquiry unit together before the research project began and so she had some previous experience with the statistical inquiry process. Elise's style of teaching was naturally open-ended and giving students ownership of their learning was a regular part of her teaching practice. Although Elise embraced the process, she was still developing an understanding of data analysis that students at this age (7-8 years old) could conduct.

> *Sometimes I wasn't sure the direction that I needed to go. I think that's, a lot of that's to do with my not really having a bigger picture about where the data could go at this year level.* [Elise, individual interview, 3 May 2007]

Being able to envision the inquiry process in a classroom setting was by far the most challenging hurdle for the teachers in the orientation phase. At the end of their first units, the teachers recognised the challenges in turning some of the decision-making over to their students. This became one of the areas in which they focused their attention in the next cycle.

Exploration cycle

After the teachers were able to envision what a statistical inquiry looked like within their classrooms, they reacted to problems that had emerged during their first unit (orientation cycle), for example, the need to carefully balance student-direction and teacher support by explicitly teaching students skills in decision-making, collaboration, and independence. They also could see the range of potential directions in different phases of the investigative cycle (Figure 1) and responded to changing management issues that arose in each of these cycles.

> Kaye: *Some still needed support; they didn't have any trouble collecting the data, they're quite happy to go out and do that. But then when the data comes back, actually looking at what they needed to specifically [answer the question]-*
> Carla: [interrupting] *Actually, we still had a bit of difficulty collecting the data. … I wasn't really sure how to … organise them going out in groups [to collect data].* [Kaye & Carla, joint interview, 17 July 2006]

Here, Kaye and Carla had completed their second inquiry unit. Once able to envision the process of an inquiry, they could now better identify and attend to giving students explicit support at key junctures. The teachers continued to find some logistical aspects challenging, like organising and coordinating group work, and helping students develop independence, but their growing experience helped them modify their teaching styles to address these issues.

Consolidation cycle

By the next stage, the teachers had developed a 'big picture' of what was involved in teaching a statistical investigation and worried less about micro-issues (e.g., classroom management, logistical issues). Their concerns focused primarily on refining the process to improve student learning. They found it easier to design and locate rich driving questions to initiate the inquiry process, and in many cases, a new interest was emerging to deepen students' understandings of content by better structuring teaching of more subtle aspects of the inquiry process. Kaye, after completing her fourth inquiry unit, discussed how her approach to teaching inquiry had changed over the course of the year and elements that she still found challenging:

> *I guess [now] I would be far more comfortable with, with letting kids go. Letting kids have a run. Whereas before I was much more structured. … I'm still not sure whether I'm trying to … do too much in an investigation, whether I'm trying to push too much through or whether I need to refine it a bit more. … Yeah, you see the connections, but then, [following those connections] seems to build into a huge amount for the kids.* [Kaye, individual interview, 29 Nov 2006]

Kaye felt more comfortable in this stage negotiating the balance between student decision-making and providing scaffolding to help their inquiry stay focused and insightful. She was more able to see connections and potential avenues to extend the inquiry but wanted to

ensure that it didn't get too big. Carla also felt more comfortable with the process of a statistical investigation and was interested in improving the support for her students' learning. Here, she expresses the need to help students make connections between the question being posed, the data they collected, and the conclusions being drawn.

> *At first I just thought that [posing a question] would be pretty logical kind of a thing, but when the kids had to pose their own, and then collect the data to answer that, and then analyse and interpret it, that was hard for them to make that connection. I think we did one big investigation, it was all of those parts, and when they got to the end, they'd forgotten what the question was. … If I did this again next year, … every time we would [keep] looking at the question and breaking it down [asking], 'What do we want to find out here?' And keeping [the question] visible the whole way through.*

Although the teachers had been told that it was difficult for students to make the connection between the question under investigation, the data they were collecting and interpreting, and the findings they were reporting (Hancock et al, 1992), the teachers needed to experience this firsthand in their own classrooms to better envision their roles in scaffolding students in this process. Carla also reported new understandings about the purpose of a statistical inquiry, helping students develop non-trivial questions to investigate, and visualising the data structure.

> *[I now see] that doing the graphs are not the key, you know, [it's] the interpreting. There's so much more that you can interpret. … Some of the questions the kids posed weren't in-depth enough or weren't asking enough. Or they didn't think about—which I think is really hard—what the data would look like, whether it would be quantitative or qualitative. And if it is qualitative, how would you graph that? Which is why some kids ended up with graphs that were a metre long and full of all different [cases], one of each [category].* [Carla, individual interview, 29 Nov 2006]

These insights were important for Carla to move students towards more purposeful examination of the problems they were investigating. The shift from focusing on graphing techniques towards interpreting data is an important step in developing deeper understanding of statistical processes and tools (Pfannkuch, Budgett, Parsonage & Horring, 2004). Carla's realisations came after teaching four units and re-emphasises the non-trivial nature of learning to teach statistical inquiry.

Commitment cycle

It was fairly clear after two years that some of the teachers were committed to not only including statistical inquiry as a regular part of their teaching but working to help other teachers develop and improve their teaching of inquiry. Kaye and Naomi were clear cases. They incorporated inquiry into lessons outside of the research study and confessed that they could now 'see inquiry questions everywhere'. In addition, they were working beyond their own classrooms to help other teachers and the profession to begin this path. For example, after 18 months in the study, Kaye requested that the principal create a new position at the school for her to work as a mentor to other teachers to implement an inquiry approach in mathematics in the lower grades (ages 6-8), and Naomi is conducting a post-graduate research project to deepen her understanding of students' engagement with inquiry. Both teachers have since joined the governing body of their state mathematics teacher organisation and provided over a dozen professional development sessions for teachers learning to conduct statistical inquiry.

CONCLUSION

The purpose of this paper has been to propose a tentative model to gain insight into teachers' evolving growth in confidence, commitment, and expertise in teaching statistical inquiry at the primary school level. Based on interviews and classroom observations, distinct stages in the teachers' experiences are emerging as they became more familiar with the process. The research is not proposing that all teachers progress at the same rate or all the way through

this model; however, a set of general principles described here can help researchers gain insight into the non-trivial nature of learning to teach statistical inquiry. The model is currently being used to help an expanded (n = 20) group of teachers progress through each stage by supporting them to recognise key elements that teachers find challenging and support mechanisms (Makar, in press) that can help them to persist through these challenges. The aim is to provide teachers, school leaders, researchers, and teacher educators with an elaborated framework for supporting teachers through the complex and slow process of gaining expertise, confidence, and commitment to teaching statistical inquiry.

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