STUDENT STORYTELLING AND MAKING SENSE OF STATISTICS: RESEARCH METHODOLOGY INSIGHTS

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With growing interest in storytelling as a pedagogy for students learning university introductory statistics, a need has arisen to develop appropriate research methodologies. This paper presents methodological insights from a study involving 31 university introductory statistics students who wrote contextualised stories about sampling distributions and the normal distribution. Data was generated using sound recordings of student interviews that captured reflections of their story writing experiences. An assumption-based, reflective analysis produced conjectures that generated preliminary research findings, which were then tested using the theoretical ideas of presupposition, subjectification, and multiple perspectives. The study's findings suggest there is value in undertaking additional research into storytelling as a pedagogy. The methodology developed offers insights not only for future researchers in statistics education but also for other educational settings.

INTRODUCTION

Many university students in introductory statistics continue to struggle to make sense of what they are learning. This has been a persistent problem and continues to be relevant today. The problem has been accentuated through increasing class sizes emerging, for example, from students enrolling in STEM courses (Science, Technology, Engineering, and Mathematics) that provide increasing employment opportunities. Increasing numbers of enrolments have led to students coming from diverse educational backgrounds with varying learning capabilities and seeing many struggling to make sense of their learning.

To address the problem, previous researchers placed emphasis on having students analyse and interpret data (Cobb, 1992), whereas others believed attention needed to be given to enhancing students' statistical literacy, reasoning, and thinking (Ben-Zvi & Garfield, 2004). Recent research interest has turned to investigating the potential of storytelling as a pedagogy to address the problem (Lemieux, 2018; Sherwood, 2018). Drawing on the preliminary work by Sherwood (2018), this paper reports on a larger follow-up study by Sherwood (2020). The research question in the follow-up study investigated *how* students' own personal, contextualized stories might help make learning of university introductory statistics less abstract and provide students with new opportunities to access their learning. This paper will focus primarily on the methodology used to generate the findings in the follow-up study.

LITERATURE REVIEW

The problem of students struggling to make sense of statistics has been tackled by numerous researchers. A central argument has been the need to move away from atomistic thinking, reliant on process and procedure to arrive at "the answer," to approaches that foster a sense of coherency for learners (Ainley & Pratt, 2006; Bakker & Derry, 2011; Rossman & Garfield, 2011). One approach championed by Cobb (2015) was to make statistics accessible to students by relying on using "context to tell a story" (p. 267). The use of stories in statistics education is relevant from the perspective that they can help contextualize abstract concepts by making them come together in a meaningful, holistic manner (Clark & Rossiter, 2008).

Storytelling in the educational literature takes on various interpretations (Noll et al., 2018). In this paper, storytelling will refer to stories that students write, tell, and share with their peers. Researchers in statistics education have recently been drawn to combining context and story to understand various aspects of students' sense making of statistics (Makar et al., 2018; Sherwood, 2020), along with researchers in humanities and mathematics (Crème, 2008; Visnovska et al., 2018). For example, Crème (2008) compared student writing of formal essays with the writing used in learning journals. The results indicated that learning journal writing, an informal style of storytelling, helped students to find different ways of knowing and experiencing new concepts. Visnovska et al. (2018) used an unmarked measuring stick to show improved student thinking in understanding fractions. With the

measuring stick at the centre of various learning stories, they found it offered students a language to connect old to new experiences.

In contrast to simply adopting a process and procedure approach, integrating the combined use of context and story introduces a dynamic, active element of learning for students to identify gaps in their knowledge for helping to make sense of statistics (Odden & Russ, 2019). Yet despite the growing interest around context and story, limited methodologies exist for understanding *how* context and story might help students make sense of statistics. Hence, this paper presents methodological insights to address the research question: *How can university introductory statistics students' own contextualized stories support them in making sense of statistics?*

METHOD
Setting

Thirty-one university introductory statistics students were interviewed over two years in a study in the School of Economics at the University of Queensland. The study was comprised of three stages. The first two stages, called the exploratory and clarification stages (2016–2017), involved 10 students who had completed an introductory statistics course (ECON1310). These stages were preliminary in nature to help develop, clarify, and refine research materials and approaches (Sherwood, 2018). The preliminary outcomes then informed a third and final stage that involved 21 participants (second half of 2018). The participants were typically aged between 18 and 21 and had completed the same introductory statistics course (ECON1310) during the first half of 2018. The course topics included descriptive statistics, probability, the normal distribution, sampling distributions, confidence intervals, hypothesis testing, and simple linear regression.

During the third and final stage of the study, informed by the earlier stages, students were required to choose either a real or imaginary context to write two short statistical stories. Each story needed to be approximately 200 words. A statistical story was defined as needing to include analogical characters and illustrations to help explain key features relevant to the normal distribution and sampling distributions and had to use language able to be understood by a child (7 to 8 years old). The combined stories created a MOSS Book (My Own Statistics Story Book), which became a course assessment task with a weighting of 5%. The other assessment tasks consisted of a mid semester exam (25%), final exam (50%), and online fortnightly quizzes (20%).

Data Collection and Analysis

Data was generated through the collaboration of participants with the researcher during semi-structured interviews (Kvale & Brinkmann, 2009). Sound recordings of participant interviews captured their reflective experiences of writing their MOSS Book pages. The interviews commenced about one month after the course grades were released and took place over five weeks. The average time for most interviews was about one hour, with participants encouraged to speak freely to explain their perspectives about their learning experiences. Interactions between the researcher and participants aimed to probe participant statements and address their moments of hesitation while helping to prompt their reflection about their MOSS Book pages (Labonte & Robertson, 1996). When transcribing the interview recordings, notes were added to capture participant reactions such as their surprise at various statements or events. Data was also generated by the researcher making written entries and observations in a reflective diary after each interview.

Analysis of the data began by identifying critical events, defined by Maher (2002) when developing ideas as a "significant advance or conceptual leap in previous understanding" (p. 5). Using the transcribed interview sound recordings, various critical events were identified using a modified approach developed by Powell et al. (2003). A series of critical events were identified when examining two female participants' interviews. Using an assumption-based, reflective analysis, 17 conjectures were generated by analysing their combined interview data and the way their contextualised stories seemed to be helping them make sense of statistics. These assumptions were categorised to generate five themes that were adopted as preliminary research findings. By drawing on the interview data from the remaining study participants, Bruner's (1986) theoretical ideas on narrative mode of thought—namely presupposition, subjectification, and multiple perspectives—were used to develop an analytical tool to test the preliminary research findings. The use of presupposition allowed tacit, rather than explicit, meaning about statistics to be revealed by exposing assumptions participants made about their learning

that they were unaware of. Subjectification allowed participants to be placed at the centre of their own story to reveal the way they personally constructed meaning. Furthermore, multiple perspectives recognised that there is no single truth, meaning participants could create very different stories to explain a statistical concept.

RESULTS

The results of the study are presented in two parts. The first part analyses data from two selected participants to demonstrate the process of generating research themes that became the preliminary research findings. The second part demonstrates how preliminary research findings were then tested using an analytical tool developed from Bruner's (1986) theoretical ideas of narrative.

Developing a Preliminary Research Finding

The following presents selected examples of critical events identified during interviews with two participants, Rebecca and Hellen (all participant names used are pseudonym). As an example of the analysis conducted in the study with Rebecca and Hellen, the following demonstrates how various conjectures emerged from their data and were then categorised into a single theme, thereby generating one preliminary research finding.

Rebecca's interview revealed how she believed creating her MOSS Book, based on a context involving eggs and their weight, was a relatively easy task. Yet by the end of the interview, she openly critiqued her work: "To be honest, in some way, I think eggs is not [making] sense…it is not very accurate." A critical event occurred when Rebecca asked to redo her MOSS Book, to address various issues she had identified during the interview about her MOSS Book regarding dispersion and distribution shape. She asked if she could have another interview after redoing her MOSS Book. In a follow-up interview one month later, she had changed the context to involve whales and their waterspout heights (Figure 1), indicating "*because I went to Hastings Point and I watched the whales ... and lots of kids were interested about whales ... so maybe I can do something about whales using their spout of water ... I could make it more interesting for them to read.*"

Rebecca went on to reveal she personally connected with whales as social animals and the importance of families. By thinking about families (pods) of whales, she created a visual link to help see how to explain the sampling distribution using average pods' waterspout heights. Analysis revealed a critical moment in the interview when Rebecca found she could make understanding the sampling distribution more visible by drawing "more whales to explain that." Stemming from the analysis, the following conjectures emerged:

- Students' stories seem to allow them to look at the world around them to see statistics everywhere. This seems to enable the visual connection to intangible, theoretical statistics concepts to tangible, realistic, familiar events in everyday life to promote sense making, and
- Stories and context seem to allow the diversity of students' everyday lives to be captured in ways that make sense to the individual, yet at the same time, provide a mechanism to capture the commonality required of specific statistics concepts.

Toward the end of Rebecca's second interview, Hellen arrived. They agreed to take part in a group interview. Rebecca informed Hellen about her whale story (Figure 1). Hellen jumped in to compare the beetles in jars she used in her MOSS Book for the normal distribution (Figure 1).

Figure 1. Normal distribution for whale spout heights (Rebecca) and beetle lengths in jars (Hellen)

In support of using personally meaningful contexts with pictures to make sense of statistics, Hellen revealed "I was scribbling all over my laptop saying … ah … no … I need more pictures." Hellen

quickly commented how Rebecca's whale story captured the normal distribution and sampling distribution ideas by observing "Oh, okay. So, they blow different heights [of water]…Nice." Their interaction allowed Rebecca to reaffirm with Hellen that "using pictures" allowed statistics concepts to become "more clear." Rebecca's own stories, along with Hellen's, helped Rebecca realise learning statistics was more than just memorising content to simply get the right answer (Bakker & Derry, 2011). These events helped generate another conjecture:

- Students' own contextualised drawings of statistics, emerging from their stories, seemed to allow them to make connections to statistics in ways that words may fail to do. It's like the saying goes— a picture says a thousand words.

Based on the three conjectures detailed in this paper, a theme was proposed that then became a preliminary research finding. Namely, contextualised stories seem to help students make sense of statistic by creating interconnectedness of statistical ideas, allowing coherency in their thinking to help them view statistics holistically.

Testing a Preliminary Research Finding Using Bruner's Ideas

Using Bruner's (1986) theoretical ideas on presupposition, subjectification, and multiple perspectives, additional participant interview data was used to test the preliminary research finding. As an example of how the preliminary research finding identified above was tested, analysis of interview data from Rachel, Mary, and Alan demonstrates the process.

Rachel

Rachel worked in a movie theatre and designed her MOSS Book using characters from the Lion King movie. Using bug length as a variable, her friend Eloise (it was a group interview) noted the bugs in the normal distribution sketch incorrectly had the same length. Rachel then realized, "*I had not fully appreciated the significance of the variable on the x-axis. It does create a nice image of a shape, but it's not correct!*"

Rachel responded in a way that explicitly highlighted her tacit assumption (presupposition) about not fully grasping the continuous nature of the horizontal-axis variable of "bug length" when using familiar and relatable characters in her story (subjectification*).* Rachel's own story, with input from Eloise, had revealed Rachel's shallow approach to appreciating variables (presupposition, multiple perspectives). Rachel's story helped her move from an atomistic to a holistic learning perspective known to foster coherence in thinking and promote sense making (Bakker & Derry, 2011).

Mary

Having Pacific Islander heritage, Mary's stories used frangipanni flower petal lengths and baskets of flowers for the normal distribution and sampling distribution. During the interview, Mary was surprised to discover that shaking a tree could be linked to randomly collecting flowers when measuring petal lengths and thinking about the sampling distribution (presupposition): "*It didn't really fit with me … I didn't think about it … We did types of sampling in the first week [of the course], and then by Weeks 5 and 6, it's not connected.*"

In other words, Mary could place herself within her own story (subjectification) to help holistically make sense of statistics. In doing so, it seemed to suggest her stories had helped promote the interconnectedness of statistical knowledge, with contextual knowledge from observable life experiences that provided a source of sense making (Makar et al., 2011). Mary started to see statistics not in isolation, but rather as concepts connected to life experiences where stories can help ideas "hang together" (Clarke & Rossiter, 2008, p. 66).

Alan

Alan discovered an unconscious misunderstanding built into his MOSS Book about a gold miner collecting nuggets during his interview. For the normal distribution, he used the weight of gold nuggets as the variable, with the average nugget weight being 15 kg. For the sampling distribution, he placed 20 nuggets in a bag and indicated the mean weight in his sampling distribution diagram incorrectly as 20*15 = 300 kg. After discussion between the researcher and Alan, there was a pronounced "ohhhhhhh" from Alan when recognising his own error (presupposition, multiple perspectives). His misunderstanding was

made explicit when he observed: "*When I was doing the exercises [in tutorials], I didn't think about this much [that the centre of the two distributions were the same value]."*

Alan's story had exposed a weakness in his understanding between the normal distribution and sampling distribution, made clear by being able to place himself at the centre of his story where he could relate to gold nuggets (subjectification). Alan came to realise his misunderstanding of the mean value in the normal distribution and sampling distribution was linked to following an atomistic approach to solving tutorial questions that relied on following a process and procedure (Ben-Zvi & Garfield, 2004). His contextualised stories had exposed this atomistic approach (presupposition), helping him make deeper connections to statistics in ways that might otherwise have been overlooked.

DISCUSSION AND CONCLUSIONS

This paper detailed a methodology that addressed the research questions of *how* students' own personal, contextualised stories might help make learning introductory statistics less abstract. By using an assumption-based, reflective analysis, one preliminary research finding from a study was presented and tested using theoretical ideas on narrative (Bruner,1986).

The methodology adopted in the study relied on identifying preliminary research findings. Then using Bruner's (1986) theoretical ideas on narrative, an analytical tool was developed to test the preliminary research findings using additional interview data to answer the research question. Previous research showed context can help support student learning of statistics (Cobb & Moore, 1997) along with the use of stories (Pfannkuch, 2011). Yet limited research into the combined effects of context and story for student learning of statistics has been undertaken, despite growing research interest in the area (Makar et al., 2018; Noll et al., 2018; Sherwood, 2020). The research highlighted the need for the development of deep, qualitative methodologies to develop greater understanding in using storytelling in statistics education. Therefore, the main contribution of this paper has been to present a qualitative methodology that offers opportunities for future researchers to investigate a story-based pedagogical approach in not only the field of statistics education but also other educational settings.

A key finding from the study suggests students' own stories seem to help form ways to create interconnectedness of statistical ideas and coherency in their thinking, enabling them to view statistics holistically. Yet what can be seen from the results is that students' contextualised stories may not instantly have them view statistics holistically. Rather, through a guided process whereby students are required to reflect on their stories, a heightened sense of coherency and connectedness seems to emerge by retelling, discussing, and receiving feedback from peers (Weick, 1995). It seems the process of modifying and reconstructing their original stories raises students' level of learning and sense making. Writing contextualised stories seemed to require students to learn in an unfamiliar way, unlike the atomistic standard teaching and learning approaches that develop computational skills to arrive at a specific answer (Bakker & Derry, 2011). The study supports the idea that there seems to be value in undertaking additional research into using storytelling as a pedagogy for providing students with a means of developing meaningful connections, coherency, and a holistic appreciation of statistics (Ben-Zvi & Garfield, 2004).

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