PRE-SERVICE SECONDARY MATHEMATICS TEACHERS' STATISTICAL PREPARATION: INTERPRETING THE NEWS

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Undergraduate mathematics programs must prepare teachers for the challenges of teaching statistical thinking as advocated in standards documents and statistics education literature. This preliminary report presents initial results from a study of pre-service secondary mathematics teachers at the end of their undergraduate educations. Although nearly all had completed a required upper-division statistics course, most were challenged by two tasks which required a critical analysis of the use of statistics in newspaper articles. Some patterns emerged in the incorrect answers, including a tendency to focus on potential sampling issues which were not relevant to the tasks. The session will explore the nature and sources of these difficulties with statistical thinking and statistical communication and it will explore the implications for undergraduate mathematics and statistics teacher preparation.

Key words: Statistical Thinking, Distributional Thinking, Teacher Preparation

Statistical literacy must be a goal of K-12 education (Franklin et al., 2007); it is essential to informed citizenry, to decision-making, and to economic empowerment (Utts, 2003). The achievement of this goal is dependent upon the undergraduate preparation of mathematics teachers who are proficient in statistical thinking and can foster that ability in their students. That is, K-12 teachers must understand and be able to communicate "the need for data, the importance of data production, the omnipresence of variability, and the quantification and explanation of variability" (Aliaga et al., 2005, p. 14). Indeed, recent K-12 standards/guideline documents, namely, the American Statistical Association's GAISE standards (Franklin et al., 2007) and the widely-adopted Common Core State Standards (CCSS) for Mathematics (CCSSI, 2010), have highlighted the importance and need for students to develop statistical literacy and engage in statistical thinking. Yet, many in- and pre-service teachers are products of a system where the learning of data and chance at the K-12 level has been underemphasized (Shaughnessy, 2006). Against this backdrop of increasing statistical demands on K-12 teachers, this preliminary report explores the statistical thinking of pre-service teachers of secondary mathematics (PSMTs) at the end of their undergraduate mathematics programs.

In particular, two statistical thinking questions were asked of 23 senior-level students enrolled in a capstone mathematics course for undergraduate mathematics majors intending to be secondary mathematics teachers. Twenty-two of the students had completed, as a pre-requisite for the course, an upper division semester-long calculus-based statistics course offered in a department of mathematics & statistics. Each of the two questions required students to comment on whether statistics reported in a newspaper article supported a claim from the article. Initial analysis indicates that (1) many of these PSMTs may be uncomfortable with statistical thinking and (2) there are some emergent patterns in the students' incorrect answers.

Perspective

In 2012, the Conference Board of the Mathematical Sciences (CBMS) released a draft of recommendations for teacher preparation. They called for statistical preparation with a focus "on data collection, analysis, and interpretation needed to teach the statistics outlined in the CCSS"

(p. 8). This type of preparation may not be the status quo; Rossman, Chance, Medina, and Obispo (2006) pointed out that many mathematics teachers "do not have ample opportunities to develop their own statistical skills and understanding of statistical concepts before teaching them to students" (p. 332). They connect this issue to the structure of teacher preparation programs in which PSMTs receive little instruction in "communication skills and statistical judgment" (p. 332). There have been few studies of teachers' statistical knowledge for teaching. Groth (2007) proposed a hypothetical framework for this knowledge and lamented that "there is a daunting amount of work to accomplish in building programs that are effective in helping teachers develop knowledge for teaching statistics" (p. 433).

Preliminary Results

The data are comprised of student work on two questions from a capstone mathematics course for PSMTs which was taught by the author of this report. Question 1 was a homework problem; there is no information about the level to which students coordinated on this task. Question 2 was assigned on a take home exam; coordination was prohibited on the exam.
Both questions required students to examine newspaper quotes. Of the semester-long course, three weeks were devoted to discussion of statistics, though no in-class activities required students to interpret news reports.

Question 1. USA Today published an article called *Is `failure to launch' really a failure?* (Jayson, 2006). Here are two sentences from it:

> i. "High housing costs are only part of the reason young adults are staying home in greater numbers than ever before."
>
> ii. "Since 1970, the percentage of people ages 18 to 34 who live at home with their family increased 48%, from 12.5 million to 18.6 million, the Census Bureau says."

(A) Does the second sentence support the statement that "young adults are staying home in greater numbers than ever before"? (Assume "young adult" means "people ages 18 to 34".) (B) Is there anything misleading? (C) What questions would you like answered in order to further clarify the provided statistics?

There were two main issues with the quotes in Question 1 which students were to identify: (1) The article incorrectly stated that the percentage (not the number) of people living at home increased, and (2) The article was misleading in its failure to acknowledge that, from 1970 to 2006, the population of the United States also increased. In fact, it increased by approximately 48% (US Census Bureau, 2012). Among the 20 responses, only one made note of Issue (1). In order to examine student recognition of Issue (2), responses were initially coded based upon whether an issue of proportionality was acknowledged. Twelve responses clearly addressed proportionality. However, three of these twelve did not mention it in connection with the primary reason why the second sentence did not support the quoted statement; instead they brought up the possibility of a population increase as one of their questions in part C.

Question 2. Here's a quote from the New York Times (Future, 2009).

> "Immigrant children lagged in mastering standard academic English, the passport to college and to brighter futures. Whereas native-born children's language skills follow a bell curve, immigrants' children were crowded in the lower ranks: More than three-quarters of the sample scored below the 85th percentile in English proficiency."

Does the statement that "more than three-quarters of the sample scored below the 85th percentile in English proficiency" support the statement that "Immigrant children lagged in mastering standard academic English"? Explain why or why not.

The intention of Question 2 was for students to engage in some form of distributional thinking. Only nine of the 23 students supplied an explanation which acknowledged that a sub-population with only 75% scoring below the 85^{th} percentile would likely be outperforming the general population. Of the 14 other students, seven did demonstrate distributional thinking to some extent. Often, however, this thinking was unproductive and inaccurate.

Some Implications and Questions for Audience

In general, the formal upper division courses typically required of mathematics majors do little to prepare them for their careers as mathematics or statistics teachers (CBMS, 2012; Monk, 1994). Rossman et al. (2006) and Groth (2007) raised concerns about the lack of appropriate statistical education for pre-service teachers. Preliminary analysis indicates that there are consequences to that lack of instruction. All but one student had completed the required upper division statistics course, yet, on Question 1, only 12 out of 20 students addressed issues related to proportional reasoning. On Question 2, only nine out of 23 successfully demonstrated distributional thinking. Indeed, many of the PSMTs, at the end of their undergraduate mathematics education, struggled with statistical thinking. Furthermore, there are some notable characteristics of the incorrect answers provided in this study. Many incorrect answers were valid observations which did not relate to the question. This may be an instance of what Kahneman and Frederick (2002) referred to as attribute substitution, often characterized by situations "in which a difficult question is answered by substituting an answer to an easier one" (p. 50). In particular, many students focused on potential methodological issues which are typically not discussed in news media, but may be discussed in statistics courses. That is, the students may have been more comfortable with discussing potential sampling issues (about which they had no information) than with a context-based critical evaluation of the use statistics in a non-academic source.

These preliminary results, accompanied by examples of student work, will be discussed in the proposed session. The following questions will guide discussion after an initial presentation:

1. What do these preliminary results and the student work suggest about these students' statistical preparation for teaching? What can be said, in general, about the undergraduate preparation of secondary level teachers of statistics?
2. With the adoption of the Common Core State Standards, this is a time of widespread K-12 curricular change in statistics. How can undergraduate teacher preparation programs help teachers meet the demands associated with these changes? What statistics education research is needed to support this? How can the challenges of institutional change be confronted?

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