STATISTICS CONTENT AND PEDAGOGY IN A COURSE FOR PRE-SERVICE SECONDARY MATH TEACHERS

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The statistics content in pre-college math courses in the US has risen considerably in recent years. In particular, the Common Core Mathematics Curriculum, which has been adopted by 45 of the 50 states, includes statistics objectives at all levels, 6-12. Nevertheless, many pre-service and in-service mathematics teachers are uncomfortable with statistical topics and apprehensive about teaching them. The prevalence of statistics in the math curriculum has created a need for teachers who are familiar with appropriate methods for teaching statistics and who have a solid understanding of statistical topics. This paper describes a teaching methods course that integrates learning about statistics content and pedagogy to prepare future secondary math teachers to teach statistics effectively.

INTRODUCTION

The Common Core Mathematics Curriculum, recently adopted by the majority of US states, has continued a trend by increasing the amount of statistics content addressed in pre-college mathematics classes. These changes reflect the need for statistical literacy in society at large. As stated in the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College report (Aliaga et al., 2005) "Every high-school graduate should be able to use sound statistical reasoning to intelligently cope with the requirements of citizenship, employment, and family and to be prepared for a healthy, happy, and productive life."

Despite the importance of statistical literacy and the growing emphasis placed upon statistics in secondary math courses, many in-service math teachers do not have a solid foundation in statistical principles. Again from the GAISE College report: "Statistics… is a relatively new subject for many teachers, who have not had an opportunity to develop sound knowledge of the principles and concepts underlying the practices of data analysis that they now are called upon to teach." Moreover, statistics teaching has additional challenges that distinguish it from mathematics teaching; as Rossman, Chance, and Medina (2006) observe "Students react differently to statistics than to mathematics." We have observed that *teachers* also react differently; thus, there is a need for courses that specifically train pre-college teachers to teach statistics.

An issue of *The American Statistician* (2005) was devoted to describing efforts at various US universities to train graduate students to teach statistics effectively. However, there are many differences between the needs of graduate students in statistics and the needs of secondary math teachers. Among these are that the math teachers, for the most part, have much less experience in statistics courses, therefore graduate students likely feel more comfortable with statistics topics than does the typical secondary math teacher. Furthermore, graduate students are able to focus solely on teaching statistics whereas the statistics content in most secondary courses is mixed in with the math content. At the USCOTS conference held in 2013, several presentations focused on issues related to preparing pre-service teachers to teach statistics though these did not specifically describe a statistics teaching methods course. (See Bagagliatti et al., 2013; Lee et al., 2013; Harrell-Williams et al., 2013).

In this paper, I describe a statistics teaching methods course for pre-service secondary mathematics teachers that integrates discussion of effective teaching practice with investigation of statistics content knowledge.

FORMAT OF THE COURSE

At Utah State University, the majority of our pre-service secondary math teachers complete a math/stat education composite degree. In addition to the work for the regular mathematics education major, which includes a calculus-based introductory statistics course, students seeking the composite degree must complete an introduction to probability course, an additional statistics course at the senior/graduate level, and the statistics teaching methods course described here.

Because of the requirements of the composite degree, the students that enroll in our teaching methods course may have had more statistics content courses than a typical pre-service math teacher; however, the content of the methods course would be accessible to less experienced students.

The statistics teaching methods course is fairly new. It has been taught three times with a typical enrollment of 10-11 students and now runs once per year. The course is primarily activity and discussion based. Students spend a lot of time developing and discussing concepts in groups and participating in activities that require them to apply material learned through readings and discussions.

For the first part of the semester, students, our pre-service math teachers, complete assignments in which they review content and become familiar with statistics education literature. They have a weekly assignment in which they investigate an assigned statistics topic. This assignment serves as a review of material they have seen in previous courses and prepares them to participate in class discussions and activities. These assignments include prompts that encourage students to consider where methods come from, why we use the methods we do, and how methods relate to each other. For instance, in examining confidence intervals, students identify a general form of a confidence interval that is applicable for estimating a variety of parameters considered in the course. Topics of these assignments include probability, distributions, experimental design, descriptive statistics, sampling, and inference. Because students have had previous statistics courses we can be selective about the topics included in the course and focus on those with which the students have the most difficulty. In particular, we emphasize big ideas, how concepts and methods relate to each other, and how to put these methods together.

Students also have a weekly pedagogy assignment. This consists of a reading from the statistics education literature and an associated task. Early readings focus on differences between mathematics and statistics and important recommendations in the field of statistics education. Students read both the preK-12 and college GAISE reports and later readings focus on recommendations for statistics teaching given in these reports. For each reading, students are required to reflect on the message of the article and write a response in which they consider the implications of the article's message for their own teaching. Along with the response, students complete a task associated with the reading. Tasks have included finding examples of statistics used in the media, identifying online sources for datasets and technological tools, and developing prompts for assessment. Through these assignments, students become familiar with recommendations from the statistics education community for effective teaching. We discuss these readings as a class and then apply the recommendations through course activities.

It is very natural to integrate discussions of statistics content and pedagogy in a single class. Not only do most of the students in this course benefit from review and discussion of statistics concepts but the content motivates discussions of pedagogy and makes pedagogical principles accessible. We further integrate learning about pedagogy and content by modeling effective teaching strategies and giving students the opportunity to develop lessons and deliver these to their peers.

REINFORCING STATISTICAL CONCEPTS WHILE *MODELING* PRINCIPLES OF EFFECTIVE STATISTICS TEACHING

In his 1912 book, *The Teaching of Mathematics in Secondary Schools*, Arthur Schultze stated that deficiencies in mathematics training were partly due "to the fact that a number of teachers have had little opportunity to become acquainted with the details of modern methods of teaching mathematics, and hence largely employ the methods by which they themselves were taught." Now, more than 100 years later, mathematics teacher training programs seek to ensure that math teachers do have the opportunity to become "acquainted with the details of modern methods of teaching mathematics," however; many are still *un*acquainted with the details of modern methods of teaching *statistics*. Moreover, because the statistics content in pre-college courses has increased dramatically in recent years, many secondary teachers are called on to teach statistics topics they never saw in school. Since "a different type of instructional preparation is needed for teaching statistics" than for teaching mathematics (Rossman, Chance, & Medina, 2006), teachers

may not be able to teach statistics as they were taught because they have few experiences as learners of statistics to reference.

In addition to teaching "the details of modern methods of teaching" statistics, teacher preparation programs can provide students with experiences as learners of statistics. As David Moore (2005) pointed out in a discussion of graduate student preparation for teaching statistics, "Training programs should themselves be models of good pedagogy." In such a program, future teachers can be involved in activities that foster active learning, use real data, employ technology, and stress conceptual understanding. They can engage in lessons that emphasize statistical literacy and use assessments to improve their learning. All of this will facilitate discussion of effective methods for teaching statistics and will provide students with models to reference.

A training program that is a "model of good pedagogy" can also be used to improve understanding of important statistical content. We introduce pre-service teachers to the details of modern methods of teaching statistics, but we follow this up by engaging our students in authentic statistics learning activities. By so doing, we give pre-service teachers examples to refer to in their own teaching, we involve them in activities that increase their enthusiasm for teaching statistics, we promote thinking about statistical problems, and we foster deeper understanding of statistical principles.

REINFORCING STATISTICAL CONCEPTS WHILE *PRACTICING* PRINCIPLES OF EFFECTIVE STATISTICS TEACHING

In his article "Learning Statistics by Doing Statistics," Smith (1998) says, "One way to help students develop their statistical reasoning is to incorporate active-learning strategies that allow students to supplement what they have heard and read about statistics by actually doing statistics." A similar idea is relevant to learning to teach statistics: pre-service teachers can supplement what they have heard and read about *teaching* statistics by actually *teaching* statistics. In order to design and teach statistics lessons, pre-service teachers must consider which methods are most effective, determine which are appropriate for the chosen content, and relate them to specified learning objectives. This process provides the opportunity to synthesize and apply what they have learned about teaching methods.

Developing and teaching statistics lessons requires pre-service teachers to reexamine statistics content as well as pedagogical principles. As the common phrase has it: "You don't know something unless you can explain it." Preparing to teach a lesson forces pre-service teachers to examine what they do know and evaluate what they do not. Sometimes an instructor thinks she knows something until a pertinent question from a student or the process of explaining it to a group shows her that she doesn't. The experience of teaching can be a powerful tool for improving the understanding of the instructor. Teaching specifically to peers in the course can be an advantage. Because of their experience with statistics, they are able to ask questions that spur discussions. We emphasize that all lessons should result in authentic learning – that is, the pre-service teachers should teach the material in a way that facilitates deeper understanding for all participants. Such a task requires the presenter to consider issues such as "why do we do things the way we do?", "what is the advantage of one method over another?", and "how do various processes relate to each other?" Each of these questions results in deeper understanding of the statistics content.

The topics covered in these lessons have been diverse, ranging from probability to sample surveys. We have observed that the pre-service teachers are enthusiastic about experimenting with various instructional approaches; in particular, they enjoy involving the classes in active learning, and in collecting and analyzing data. They have enthusiasm for teaching statistics and are eager to get the students involved in and excited about learning. In end-of-semester evaluations of the course, students commonly rank these lessons as the one of the most useful parts of the course.

CONCLUSION

Students' responses to the course have been very positive. In particular, students comment that they gain a better sense of the relevance and ubiquity of statistics and the need to actively engage students in statistical thinking, and an understanding of how statistical methods relate to one another. One student commented "Students need to understand what is going on in the world around them, and statistics is becoming a bigger part of that world."

As mentioned above, students have commented that they found the opportunity to plan and lead activities particularly useful. As the pre-service teachers develop and present lessons they are able to experiment with various teaching strategies, to practice what they have learned about statistics teaching, and to integrate principles of effective instruction into their personal teaching philosophies. In future semesters, I hope to make this an even larger part of the class following the pattern described by Andrew Gelman (2005) for his course on Teaching Statistics at the University level: "After the first third of the semester or so, we gradually shift the responsibility to the students. Each week, we pick a demonstration or class activity… and we assign two of the students to prepare the demonstration for our teaching class." Putting the course into the hands of the students earlier on will give them more opportunities to practice and reflect on the principles they are learning.

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