A CASE STUDY IN COLLABORATION PREPARING SECONDARY EDUCATION TEACHERS

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Although the mission of mathematics education departments or programs is to prepare the next generation of secondary education mathematics teachers, the question still remains, "Who should provide the training in statistics education for these future teachers?" We propose that statistics education should be provided by statisticians in collaboration with mathematics educators. We describe a model that has been designed recognizing how statistical reasoning differs from mathematical reasoning and implemented incorporating how classroom pedagogy is consequently affected.

MOTIVATION AND OBJECTIVE

Many mathematics education students upon graduation will be assigned to teach a statistics course in high school. In the United States of America, such a course is most often called "Advanced Placement Statistics" for which high schools students who score high on a comprehensive standardized examination can receive college credit. Yet, some new mathematics teachers have taken at most one statistics course during their undergraduate education and that course is often only an introductory statistics course for 'general education' credit. When placed in a high school classroom to teach statistics, they often feel unprepared and naturally proceed in the direction of teaching statistics as a mathematics course. The teacher and his or her students are frequently frustrated by the process and disappointed in the results.

Our objective was to design an introductory statistics course so secondary education teachers could learn statistics and learn how to teach statistics in the same course. The course is a collaborative effort between the Statistics Department and the Mathematics Education Department. The only prerequisite for the course is for a student to have completed a two-course sequence in differential and integral calculus.

It has proven vital to the success of the course for students to see the course as central to their mathematics education preparation and not as an 'add-on.' It is common for students to see a class outside of their major as a peripheral course and one that should receive secondary importance when allocating their time and effort. This course is taught by the Statistics Department in collaboration with the Mathematics Education Department. The Mathematics Education Department explicitly shows its students that the course is a key element in their training to be teachers. Reciprocally, the Statistics Department emphasizes not only statistics theory and methodology in the course but also teaching pedagogy.

STATISTICS EDUCATION PHILOSOPHY

Franklin and Mewborn (2006), when describing the shared responsibility of mathematicians and mathematics educators for the preparation of mathematics teachers state that the *Guidelines for Assessment and Instruction in Statistics Education (GAISE)* "framework portrays statistical analysis as an investigatory process that helps students turn loosely formed ideas into scientific studies by:

- understanding the problem at hand and formulating one or more questions than can be answered with data;
- designing a plan to collect appropriate data;
- analyzing the collected data using graphical and numerical methods;
- interpreting the analysis to reflect light on the original question."

These four steps are an abbreviated statement of the so-called "scientific method." For K-12 students, this provides a basic yet essential scaffolding structure to use in developing the logic to do empirical investigations. This is not the way mathematics is taught. Mathematics is

 In C. Batanero, G. Burrill, C. Reading & A. Rossman (Eds.), *Joint ICMI/IASE Study: Teaching Statistics in School Mathematics. Challenges for Teaching and Teacher Education. Proceedings of the ICMI Study 18 and 2008 IASE Round Table Conference.*

taught with proofs and derivations with “one right answer” and with all mental effort being directed toward developing procedural skills that will assure the student of finding ‘one right answer.’

Nicholson and Darnton (2003) conclude that reasoning with data requires different skills from those needed in mathematics. Peck and Gould (2005) concur that while statistics is a mathematical science, it differs from mathematics in fundamental ways. Gattuso and Pannone (2002) noted that at all school levels, not surprisingly, teachers taught statistics with a mathematical approach and that after experiencing a data oriented approach to learning statistics the teachers recognized the need to change their style of teaching statistics in order to be effective.

Chadjipadelis (1999) describes a course for teaching teachers to teach statistics organized around three items:

- Teaching material (content);
- Teaching process (pedagogy); and
- Teaching methods (tools).

The course we designed is similarly structured. It is designed to help students not only to learn the course content but to also experience an effective pedagogy that matches the GAISE framework, using tools that they can later use in their own teaching. However, the course is structured also for the students to explicitly reflect on the process of learning and of learning statistics in particular. This approach is similar to the approach used by Peck and Gould in their *Insight into Statistical Practice, Instruction and Reasoning (INSPIRE)* program in which they wanted participating teachers to be thinking ‘how can I teach this in my classroom?

Franklin and Mewborn (2006) summarize the pedagogical guidelines suggested by the GAISE framework as follows:

- Both conceptual understanding and procedural skill should be developed deliberately; but conceptual understanding should not be sacrificed for procedural proficiency.
- Active learning is pivotal to the development of conceptual understanding.
- Real-world data must be used where possible in statistics education.
- Appropriate technology is essential in order to emphasize concepts over calculations.

Congruently, the course we designed emphasizes conceptual understanding, interpreting results more than obtaining results, using active-learning and student generated data, and analysis assisted by–but not dependent upon–useful technology.

COURSE DESIGN

While studying mathematics is focused on the reasoning needed for derivations and proofs, studying statistics is focused on the reasoning needed to extract meaning from data and to interpret the data in a “real world” context. When learning mathematics, typically students are given data to use. When learning statistics, it is essential for students to collect data and understand their origin to appropriately analyze the data and fully interpret their meaning (Franklin et al., 2005). Consequently, this course is designed to be highly experiential. The core of the course is comprised of 56 experiential investigations where students collect, analyze and interpret data. One-hour class sessions are held three times per week, and students meet together in lab an additional two times per week.

The course is organized based on Bloom’s taxonomy of learning cognition (Andersen & Krathwohl, 2001). Every learning activity is tied to Bloom’s taxonomy, and students continually note where an activity contributes to their depth and breadth of learning according to the structure in Table 1.

Table 1. Organization of the course

Cognition Level	Learning Activity and Assessment
Knowledge	Pre and Post Chapter Quizzes
Comprehension	Directed Readings
Application	Homework Exercises
Analysis	Experiential Investigations
Evaluation	Critiques of Media Articles
Synthesis	Learning Journal and Course Essay

The emphasis throughout the course is on conceptual mastery rather than superficial coverage of material. Uniquely in the course the learning activities and assessment activities are one and the same. Consequently, learning takes place actively in real time. The same for assessment; grading is done in class and lab immediately when students complete their work. The grader provides prescriptive feedback, and the students are permitted–in fact encouraged–to respond to the grader's feedback. After a student follows the prescription for additional learning, an assignment can be redone and submitted again for reassessment. This creates a "No Limit on Learning" environment.

The intent in the design of the course is for the class to operate as a learning community wherein everyone is responsible for each other's learning. It is a "One for all and all for one" cohort organization. The students who are 'ahead' help the other students. Each student chooses a 'Study Buddy' with whom to work, and the students are further organized into groups of six within labs of 18 students. Since the course emphasizes mastery of course concepts rather than coverage of material, the class proceeds only as fast as all students can precede together to achieve mastery.

The text for the course is one of the most popular Advanced Placement Statistics texts in the United States (Peck et al., 2008). So, it is a text the students actually could use in their teaching after graduation.

PEDAGOGICAL TECHNIQUES

The desired outcome is for students to construct personal meaning by making the cognitive connections that provide the greatest congruence to achieve sustained deep learning. To this end, some of the pedagogical techniques among many used in the course are:

- learning community with responsibility for self and others' learning;
- active learning;
- experiential discovery;
- interactive peer engagement;
- cooperative, non-competitive environment;
- demonstration of mastery in a skill hierarchy;
- cognitive scaffolding;
- multiple practice opportunities;
- metaphors and analogies;
- critical reflection;
- discourse and writing;
- intellectual openness;
- timely and prescriptive feedback; and
- individualized assignments.

By utilizing a rich array of pedagogical techniques, the course strives to engage each and every student as fully as possible through whatever technique best helps a particular student. While the students are working in class, the instructor circulates through the room assisting, guiding and re-enforcing the learning activities. In this way, group instruction

becomes almost individual instruction. The instructor 'lectures' only when it is the most pedagogically effective way to respond to specific questions from multiple students.

For every learning activity in the course, students focus reflectively on two key questions:

- What did I learn about statistics from this activity?
- What did I learn about learning statistics from this activity?

They write their responses in a personal Learning Journal. As has been said, "Writing is learning", so students use writing extensively to clarify thinking, solidify learning, capture the experience, and preserve a record for future reference. Consequently, the most significant outcome from the course for many students is the creation of their Learning Journal since it synthesizes their learning experiences into a document they will be able to use as a reference in the future when they teach statistics.

At the end of the course, during the final examination week, students prepare an essay describing the personal paradigm for teaching statistics they have developed during the course. They are asked to review their Learning Journal and then to reflect upon and answer two questions:

- What are three core concepts of statistics that you learned and will use as foundational cornerstones in teaching statistics? Why did you select these three?
- What are three pedagogical techniques that you learned and will use in your teaching? Why did you select these three?

SOME EVIDENCE

At the end of the course, students' anonymous evaluations of their experience are collected by the university. Using a scale from 1 (Exceptionally Poor) to 8 (Exceptionally Good), the mean student rating for the course has been 7.2. Similarly, when asked about the "amount learned" and "intellectual skills developed", students have rated the course 7.5 and 7.4, respectively. Some comments from students indicate the course design supports the achievement of our objectives for students to learn statistics and learn how to teach statistics:

- "Learning statistics can be fun. I wish all of my classes were like this one."
- "I can't believe I learned so much in this class. I don't think I could have learned this much in any other way."
- "This is how I want to teach all of my classes when I'm a teacher."

In this course, future teachers see application of teaching principles they learn in their teaching pedagogy classes being used in their statistics course. They often describe their experience as an epiphany–"Wow! These teaching techniques really can be used, and they really work!" and "I am learning to be a teacher while learning statistics!" This is evidence we have achieved a measure of synergistic mutual support between mathematics education and statistics education.

OUTCOMES

We have found evidence that students can learn statistics and learn how to teach statistics in the same course. It would, of course, be ideal for students to have more than one course in statistics as they have multiple courses in pedagogy. Yet, this course has successfully combined learning a new discipline with learning how to teach in that discipline. While doing so, students produce a personal work product, their Learning Journal, they can use as a teaching resource in their professional careers.

We have identified three keys to success in preparing secondary education teachers to teach statistics:

- collaboration and mutual support between statistics educators and mathematics educators;
- emphasis on learning new material while learning how it can be taught effectively; and
- creation of a personal paradigm for teaching and for teaching statistics.

Since this approach is not dependent upon technology, we see no reason it cannot be used in all economic and cultural settings. Simple experiential investigations, emphasizing reflection and using writing to facilitate learning, do not require technology or an intense economic investment. It is the focus and design of the course that matter not access to a particular text or availability of technology.

CONCLUSIONS

This course is the one and only statistics course students take during their training to become secondary education teachers. The central goal of the course is for students at the completion of the one-semester course to be able enter a secondary education classroom and immediately teach statistics. After designing this course and pilot testing by the Statistics Department, the overall design was presented to the Mathematics Education Department. Their response was solidly enthusiastic.

To quote the Mathematics Education undergraduate advisor, "This is exactly what we want for our students, and we would not be able to do that." Another member of the mathematics education faculty who had taken the course ten years previously as an undergraduate student said, "I have a graduate minor in statistics now, and I have reflected many times since taking this course (when it was taught as if it was a mathematics course) that statistics and statistics pedagogy are different from mathematics and mathematics education. This approach is ideal. I wish it had been taught this way when I took it."

Such support and endorsement from the faculty is vital for student engagement. Without it, the students are resistant to developing new skills in quantitative problem-solving and analysis. They typically display the attitude, "We do not do things that way." Confirmation by the mathematics education faculty that "statistics is different from mathematics, i.e., different analysis skills" and thus "statistics must be taught differently than mathematics, i.e., different teaching skills" was vital to the success of the course.

Collaboration between the Mathematics Education and Statistics Departments was the key to success. Collaboration was achieved by mutual recognition of the central goal of the course–students will be able to teach statistics at the secondary education level after one course–and the central issue in the design of the course–learning and teaching statistics is different from learning and teaching mathematics. Both the Mathematics Education and the Statistics Departments agreed that "statistics should be taught by statisticians in collaboration with mathematics educators."

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