TEACHING STATISTICS WITH LECTURES OR ACTIVITIES: A COMPARATIVE STUDY

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Many recommendations for teaching statistics with less lectures and more student-centered methods have been proposed. Nonetheless, there are only a few comparative studies in which an entire course was taught using lectures in one section and student-based methods in another section. In order to gather information about which method produces higher student understanding of statistical topics and ability to apply statistical procedures, a sample of 74 students in a university introductory statistics course was divided into two sections. One section was taught entirely with lectures. The other section was taught using minimal teacher-centered activities; methods included hands on activities, discovery based units, and group work. Students' results on exams were analyzed. The lecture and activity sections were compared to determine which method produced higher results on conceptual questions, and which method facilitated higher results on procedural questions. Implications for using student-centered teaching methods to improve introductory statistics classes are discussed.

INTRODUCTION

Since the 1980s, interest in statistics education has grown, resulting in an increase of statistical education research and literature. As the number of students taking introductory statistics courses has risen, the need for an improved statistics course has become apparent (Moore, 1997). A multitude of ideas on how to change the introductory statistics course have been presented (Garfield, 2002; Moore, 1997). The prevalent suggestions include more focus on concepts, more active learning, and more technology (Aliaga et al., 2010; Moore, 1997). However, while many teachers are trying to introduce innovative methods, a substantial number of teachers and professors find themselves resorting to the old standby of a lecture (Meletiou-Mavrotheris et al., 2007).

The literature is unclear on whether using the reform methods increases students' understanding (delMas et al., 2007) and the majority of evidence supporting the use of reform methods in statistics is anecdotal (Weltman & Whiteside, 2010). Some studies have shown more positive attitudes or higher test scores with active learning techniques (Batanero et al., 2004; Carlson & Winquist, 2011; Keeler & Steinhorst, 1995), while other studies have shown little or no effect on student learning outcomes (Pfaff & Weinberg, 2009; Meletiou-Mavrotheris et al., 2007). Finally, some studies have shown a detrimental effect when using active learning methods (Weltman & Whiteside, 2010; Brandsma, 2000).

A gap in the existing research is that few comparative studies have been completed in which a statistics course has been taught using lectures in some sections and reform methods in other sections. There are even fewer studies in which the sections were taught for the same course, in the same semester, and by the same teacher (Giraud, 1997). The majority of the existing studies on statistics education examine the results of integrating a few activities into the existing lecture course (Brandsma, 2000; Batanero et al., 2004). Other studies have been conducted by teaching a lecture course and implementing cooperative learning for part of the class time (Keeler & Steinhorst, 1995; Giraud, 1997). Studies that actually teach the entire statistics course with reform methods are very rare.

As there is little data comparing student results in lecture versus activity based statistics courses, it is important to conduct further research in this context. The defining purpose of this research study was to determine if the activity based teaching method resulted in higher student comprehension of statistical concepts and greater ability to apply statistical procedures.

METHOD

Two sections of an algebra based, introductory statistics course were taught during the spring semester 2013 at Utah State University. One section was taught with traditional lecture

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methods; the other section was taught using active learning methods. The sections will henceforth be referred to as the lecture and activity classes, respectively. The activity class was taught with as little lecture as possible. Teaching methods for the activity class included group work, group activities, class activities, and technology. The two sections covered the same content; students completed the same homework and took the same exams. Jennifer Loveland taught both sections.

Students who needed the course for their major self-selected one of the two sections, presumably based on time constraints. Participants were not told in advance that the two sections would be taught differently. No significant differences were found between students in the two sections with respect to previous GPA, gender, or pretest scores. Forty-three students participated in the lecture class; only 31 students participated in the activity class due to seating constraints. Each section met four days a week for fifty minutes.

Format of the Lecture Class

Direct instruction was used for the entire course. Students in the lecture class did not attend any type of instructional session that was not lecture based. Since the goal of the study was to compare traditional lecture and activity approaches to teaching statistics, the methods used in the lecture class were kept similar to the instructor's past experiences as a student and teacher.

Students were occasionally given two to four minutes to work on a problem on their own, but only when the instructor felt that sufficient examples had already been covered. Students did not work together. During the lectures, an attempt was made to stress the concepts behind the procedures. A few applets and simulations were used during the lectures. The applets and simulations chosen for the lecture class had been used previously by the instructor in other lecture based statistics courses.

Format of the Activity Class

The activity class consisted primarily of student-centered activities. Students were involved in a variety of activities including: class or group activities to gather data, teacher led activities to discover statistical concepts, and group activities to discover and implement statistical concepts. The primary method of instruction was group activities. The best description of the course would be a workbook approach that incorporated physical and technological activities. Direct instruction in the form of lectures was used only when deemed absolutely necessary. The lecture segments were kept to a minimum and comprised a minority of the class time. On average, less than 10% of the class time was spent in direct instruction, with no lectures used on 27 out of 53 days. The typical reasons for direct instruction were to discuss the results from a student activity, introduce a new topic, or to demonstrate a new procedure with an example.

An activity workbook was designed by the instructor for the course using a constructivist approach. Students were typically given pages from the workbook to work on each day. The instructor would circulate among the students asking and answering questions. The students were encouraged to work together, asking questions and explaining their thought processes to their partners. To facilitate immediate feedback, keys were available to the students as they worked with their groups. The immediate feedback often resulted in cognitive dissonance and learning opportunities.

Students were allowed to self-select their partners. Partnerships varied from day to day, but held fairly constant. Students were always allowed to work in groups of four if they desired, but usually chose to work in pairs. For some activities, they were required to work in groups of four.

The main focus of the activity class was to discover and understand the statistical concepts. Even though conceptual understanding was stressed in the lecture class, the activity class structure led to even more emphasis on conceptual understanding. Additionally, students were often asked to make predictions about a phenomenon or concept.

The activity structure of the class allowed for more time to gather data. This led to the opportunity for more real data sets, particularly data in which the students had a vested interest. The activity students also had the opportunity to use physical and concrete activities. In addition, the activity class was exposed to more technology and applets than the lecture class. Students had the chance to explore the applets themselves, rather than watching the instructor use the applet.

RESULTS

An independent t test for the students' total points on all exams, showed that on average students in the activity class scored significantly higher than students in the lecture class (Figure 1, $t = 2.99$, $p = .0038$). The 95% confidence interval for the difference in the means was 1.74% to 9.81%. This suggested that the activity based teaching method supported greater student understanding of statistical concepts and ability to apply statistical procedures. The exam questions were also broken into procedural and conceptual categories. Students in the activity class performed significantly higher on procedural questions ($t = 2.57$, $p = .0123$) and conceptual questions ($t = 3.05$, $p = .0032$). The 95% confidence intervals for the difference in means for conceptual questions and procedural questions were 1.59% to 8.58% and 1.13% to 11.26% respectively.

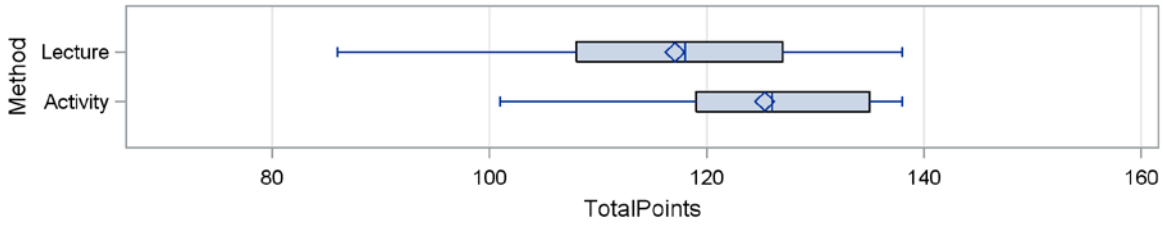

Figure 1. Distribution of total exam scores by teaching method

A regression model for the individual student's total points was computed with the possible explanatory variables of pretest scores, teaching method, previous GPA, percentage of attendance, homework scores, gender, whether they had taken a previous statistics course, and the interaction between teaching method and previous GPA. The teaching method ($p = 0.0364$) and previous GPA ($p < 0.0001$) were the only significant predictors. This model suggested that the activity teaching method had a positive result on student exam scores, but that exam scores were affected by previous GPA as well. There was also a lot of individual student variation in exam scores (Figure 2); only 34.76% of the variation was explained by the model.

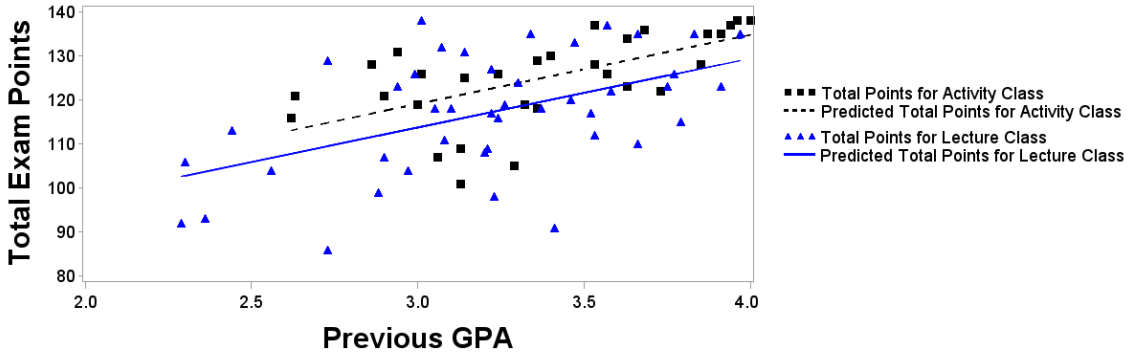

Figure 2. Distribution of total exam points by previous GPA and teaching method

Students were asked how they felt about the activities, in regard to how well they learned the material. At one month, 61.3% of students responded that they liked or loved the activities. This increased to 82.1% at three months. At the end of the semester, students were asked which teaching method they would prefer if they took another statistics class. The majority first choice was for the teacher to introduce the topic for ten minutes and then the students would work in groups. The common second choice was teacher guided class activities for the entire period (Table 1). We were surprised to see such a low preference for group work.

DISCUSSION

It is important to note that our sample size ($n = 74$) was fairly small. The results presented here may not be representative of all introductory statistics students and courses. More comparative studies need to be conducted before we can be sure that activity based methods are effective.

Our research suggested that students learned better in the activity based approach as measured by exam scores. However, the previous GPA of each student also had a large impact on exam scores. Our regression model didn't explain much of the variation in exam scores, leading us to believe that unobserved individual student characteristics greatly affected exam scores.

While students were resistant to the new methods initially, survey results suggested that the majority of students enjoyed the activity class when compared to a lecture based course; however, students indicated a preference to have more teacher centered activities, specifically for the teacher to introduce a topic for the first ten minutes before they commenced group work. Most of the students did not wish to have group activities for the entire period.

Previous research hasn't clearly shown the advantage of using activity based teaching methods in statistics. However, the data gathered in this research study provides a little more evidence for the effectiveness of using activities. As more research is conducted on teaching statistics with activities, we will gain a deeper understanding of the results of using non-lecture based methods for teaching statistics.

Table 1. Students' preferred teaching method for a future class

Preferred method	First choice	Second choice
Group work	2	4
Teacher introduce topic then group work	20	4
Teacher guided class activities	3	18
Traditional lecture	5	4

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