AN EMPIRICAL CONSIDERATION OF A BALANCED AMALGAMATION OF LEARNING STRATEGIES IN GRADUATE INTRODUCTORY STATISTICS CLASSES

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ABSTRACT

This study considers the effectiveness of a "balanced amalgamated" approach to teaching graduate level introductory statistics. Although some research stresses replacing traditional lectures with more active learning methods, the approach of this study is to combine effective lecturing with active learning and team projects. The results of this study indicate that such a balanced amalgamated approach to learning not only improves student cognition of course material, but student morale as well. An instructional approach that combines mini-lectures with in-class active-learning activities appears to be a better approach than traditional lecturing alone for teaching graduate-level students.

Keywords: *Statistics education research; Graduate-level education; Active learning; Collaborative learning; Lecture-based learning; Team projects; Classroom instruction*

1. PURPOSE

Theresa is typical of most graduate students I meet in the first statistical course of their program. Sitting uneasy as we go around the class making introductions, Theresa starts out with basic information about herself, and then exclaims "To be honest, I have tried avoiding this class for as long I could! I'm scared to death of statistics!" She isn't alone.

Students often consider statistics as the "worst" course they take while in college (Hogg, 1991). For instructors, there is often a struggle with how best to reach students, to help them learn statistics, and to help them become practical consumers of the knowledge – especially when students enter statistics courses with negative self-images. As some of this negative imagery comes from the massive amounts of formulas students can face while in the course, one solution is to structure an introductory statistics course (possibly all statistical courses) around data analysis versus mathematical technique. Another solution is found in innovative instructional paradigms in which the traditional lecture, with students passively listening, is replaced with more hands-on activities.

Yet in graduate statistical education, the actual implementation of these different approaches into a classroom setting can be quite challenging and confusing. Many of these approaches involve unique learning opportunities which have not customarily been incorporated in traditional graduate-level statistics classes. Moreover, because most research has been conducted on undergraduate statistics classes (see next section), one might ask "Would the same techniques of active or cooperative learning *actually* work in a graduate introductory statistics class? Or possibly in more advanced classes?"

Statistics Education Research Journal, 8(1), 106-130, http://www.stat.auckland.ac.nz/serj

The purpose of this research is to consider alternative instructional methods in the teaching of introductory statistics to graduate students. Based upon personal informal surveying of graduate instructors, some feel uneasy about totally doing away with lecturing, especially when teaching graduate level courses. Indeed, for many graduate instructors I have interviewed, incorporation of innovative strategies is still foreign and they feel uneasy about abandoning a lecture-format class. Thus, I decided to embrace these teaching strategies and see whether, indeed, innovative strategies work in higher level statistics education. This particular study considers the possible linkage of research in undergraduate introductory statistics to a graduate-level introductory statistics class. Future research will consider the use of such teaching strategies for more advanced statistical classes.

The “balanced amalgamated” approach to teaching (with both traditional lecture and active learning) of interest in this study would allow many graduate instructors the opportunity to explore the advantages of active learning without the concern of losing the benefits of lecturing. Thus, the purpose of this research is to compare various amalgamated instructional models that involve lecturing and active/cooperative learning in graduate statistics classes. Comparisons were made with previous semesters in which these approaches were not undertaken. Specifically, this study attempted to answer the following research questions:

1. Can active or cooperative learning be successfully implemented and accepted in graduate introductory statistics classes? Can these strategies be combined with lectures to create a balanced amalgamated instructional approach?
2. Does more active student involvement help graduate students learn introductory statistics?
3. What benefit in affective and cognitive measures is seen by introducing active or cooperative learning along with lectures in graduate introductory statistics education? As males and females may gravitate toward different teaching approaches, do these benefits differ by gender?
4. Does a particular amalgamation work better than others with graduate students?

2. THEORETICAL FRAMEWORK

The question of how a student best learns statistics has been much considered in articles on statistics teaching (e.g., Chance, 2005; Gal & Garfield, 1997; Garfield, 1995; Lovett & Greenhouse, 2000), and has mainly focused on instructional content or methods. In terms of instructional content, many statisticians, including Bradstreet (1996) and Cobb (1991), are convinced that an introductory statistics course should emphasize data analysis over mathematical technique and concepts over formulas. Hogg (1991) stressed that statistics should not be presented as a mathematics course at all. Rather, the andragogy should emphasize statistical reasoning and thinking rather than algebraic precision.

Hogg (1991) further describes the problem of traditional instruction of statistics in terms of instructional design: Students are passive learners and do not directly come into contact with the many issues that occur in data collection and analysis. He suggests students would be better off generating their own data rather than utilizing a data set from a textbook or instructor. By working with projects involving their own data, students have opportunities to define problems, formulate hypotheses, design experiments, and have genuine data to analyze and summarize. In support of Hogg, Snee (1993) emphasized that because collecting data is the nucleus of statistical analysis, learning that centers on the analysis of real data that students collect connects them to the practicality of statistical thinking. Singer and Willett (1990) argued that real data should be the nucleus of all statistical education, although their emphasis was more on using available datasets and not on students collecting their own data.

Emphasizing this statistical content also leads to a more active involvement of students in the course, and the traditional lecture approach in teaching statistics has had much criticism in the last two decades of research (e.g., Delucchi, 2006; Garfield, 1993; Giraud, 1997; Moore, 1997). Garfield (1995) suggests that students learn best by constructing knowledge and becoming active participants in the learning process. Smith (1998) indicated that

> 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 -- designing studies, collecting data, analyzing their results, preparing written reports, and giving oral presentations. (¶ 3.7)

Steinhorst and Keeler (1995) is another great resource in this matter. In support of an active-learning approach, Bradstreet (1996) writes that "Learning is situated in activity. Students who use the tools of their education actively rather than just acquire them build an increasingly rich implicit understanding of the world in which they use the tools and of the tools themselves" (pp. 73-74). Thus in this study, "active learning" refers to any activities in which the student participates and learns in a non-passive way (e.g., simply answering questions from the teacher would not be considered "active learning" in this study).

There are a variety of ways in which to incorporate active learning and projects into instruction, in particular, personal collection of data. These might include some of the following: computer simulations (Garfield & delMas, 1991); laboratory-based courses (Bradstreet, 1996); in-class activities (Dietz, 1993; Gnanadesikan, Scheaffer, Watkins, & Witmer, 1997); a single three-week project (Hunter, 1977); or a course-long project (Chance, 1997; Fillebrown, 1994; Ledolter, 1995; Mackisack, 1994).

In regard to cooperative learning, many researchers have reported significant accomplishments from introducing cooperative learning experiences in introductory statistics classes (Dietz, 1993; Jones, 1991; Keeler & Steinhorst, 1995; Shaughnessy, 1977). Teams help encourage cooperative learning, develop team-working skills, and usually build substantial friendships (Smith, 1998). However, some of this research tends to limit such activities to external learning situations such as homework or studying. Although much research exists indicating the effectiveness of alternative teaching techniques, how a teacher should implement such teaching strategies is not always clear and should be a point of more research (Garfield, 1995). Johnson and Dasgupta (2006) found that undergraduate students predominately prefer non-traditional instructional styles. Yet, exactly how a class should be structured and which techniques work best with each other was not considered in this research and would seem to be of importance to instructors wishing to incorporate such styles. Jordan (2007) stressed that the implementation of such instructional styles is open to much interpretation. In fact, some research has indicated that the implementation of these techniques does not always happen. Cobb (1993) investigated the results of various NSF grants whose purpose was to significantly improve statistical instruction, and discovered that none of the grants involved team projects, nor cooperative learning situations. Bryce (2005) indicated that few textbooks have embraced these new ideas in statistical education.

Furthermore it is not clear which methods work better for different students. Students have differing learning styles. Ford and Chen (2002) showed that males and females performed differently under various teaching styles. Kolb (1984) provided a model of learning styles: concrete–abstract and reflective–active. The combinations of these styles indicate learners that are labeled as accommodators (concrete, active), divergers (concrete, reflective), assimilators (abstract, reflective), and convergers (abstract, active). Grasha (1996) suggested bipolar characteristics of learning styles: competitive vs. collaborative, dependent vs. independent, and participant vs. avoidant. Regardless of the label, research has shown that students vary in how they best learn. Thus a class structure that only emphasizes one learning style (e.g., lecture or active learning) might in fact disadvantage some students in the attempt to reach others. In terms of classroom dynamics and pedagogical styles, Grasha identified five teacher styles: expert, formal authority, personal model, delegator, and facilitator. One can see in these labels the full spectrum of classroom dynamics from pure lecture (expert) to pure active/collaborative learning (facilitator). Instruction that flows in and out of these different dynamics would in essence touch on the diversity of learning styles of students.

Lovett (2001) said that "a successful route to improving students transfer of statistical reasoning skill may rely heavily on integrating instructional and cognitive theory, while maintaining a link to the realities of the classroom" (p. 348). Some research has considered the effect of combining different instructional techniques to create an amalgamated approach in teaching statistics. Ward (2004) created an amalgamated class consisting of online and face-to-face classes and found little difference in student performance. Keeler and Steinhorst (1995) created an amalgamated class consisting of collaborative groups and mini-lectures. They showed an improvement in students' attitudes and grades when incorporating more active student involvement with lectures. Their research focused on undergraduate, introductory-level statistics classes. No research has been found that applies such techniques to graduate-level statistics classes.

In fact lecture-based approaches appear to still dominate graduate-level statistics classes. A preliminary study by this researcher which interviewed 14 graduate instructors from colleges and departments of Education, Business, and Statistics at four major universities in the United States found this tendency, and when asked about the possibility of utilizing different learning strategies in their higher-level statistics classes, the response is typically expressed somewhat like "Yes, that may work for an undergraduate statistics class, but it would never work in this class. This class is too high level and demands a lecture format be predominant or even exclusive." Although these instructors are familiar with the vast research on innovative learning strategies in statistical education, there appears to be a huge gap between knowledge and practice. For these instructors, whether the same results shown in undergraduate statistics education would apply to graduate students has been minimally investigated.

Bligh (2000) suggests that lectures do have their place in education, yet the problem lies with instructional strategies that have unrealistic expectations. For example, Bligh indicates that whereas lectures are good at imparting ideas, they are not as good at motivating students: "Use lectures to teach information. Do not rely on them to promote thought, change attitudes, or develop behavioral skills if you can help it" (p. 20). For Bligh, many critics of lecture-based approaches in instruction almost de-emphasize the role of lectures completely. Yet, the complexity of graduate-level statistics classes suggests that some form of lecture might be beneficial. It has been this researcher's own observation that a statistics class that revolves around total active learning does not provide students with enough security in statistical methodology, especially for more advanced statistics classes. Often students need to see things demonstrated before they can apply those techniques to real life. However, this does not exclude the possibility of incorporating many of the proven techniques that have been shown to make a difference in undergraduate education.

3. RESEARCH DESIGN

Due to various limitations in the study (detailed below), a quasi-experimental design was implemented for this study. Specifically, an “untreated control group design with dependent pretest and posttest samples” (Shadish, Cook, & Campbell, 2002, p.137) was used for this study. More details on the sampling, treatment, instruments, and statistical analysis used in this design are detailed in this section.

3.1. PARTICIPANTS

The data were collected from three graduate educational statistics classes conducted at a major university over a period of three consecutive semesters. The classes consisted of both master’s and doctoral students (approximately equal ratio). Specially prepared notes by the author served as the textbook in all classes. All classes were exposed to the statistical package *R*. Although the class is offered by an Educational Psychology department, students from many different departments and colleges at the university take the course. These other colleges/departments included Social Work, Communications, Journalism, Psychology, Business, and so on. The first semester students received the traditional lecture, the second semester class added the active learning element, and the third semester added the team projects. The designs of these instructional approaches are discussed in the next section. The first semester class (lecture only) consisted of 59 students, the second semester class (lecture + active learning) consisted of 44 students, and the third semester class (lecture + active learning + team projects) consisted of 47 students. Some demographic characteristics of the classes over varying semesters were considered (specifically major, gender, race, and number of previous statistics courses), and similar frequency patterns were found between all classes. Age was obviously a bit higher on average for doctoral students than master’s. The average age for all classes was 25, with each class having ages ranging from 21 to 35.

3.2. INSTRUMENTS

Various affective measures were taken from a series of items developed and validated by the university at which the research took place. A bundle of items dealing with course content and instructional assessment were used in this study. This instrument consisted of eight items measured on a 5-point scale ranging from “poor” to “excellent.” Only four of the eight items were used in this study as they dealt directly with the subject of this study. The items included such evaluations as “communication of ideas and information” and “stimulation of interest in the course.” These affective measures were given before the final cognitive measure which is described next. Because these items were not used in a scalar sense, the psychometric properties of the scale of items are not discussed.

The cognitive measure was taken from a master list of questions which was developed by the researcher over a 10-year period. The master list contains 100 multiple-choice questions, each with three distracters and one correct answer, covering topics in regression and hypothesis testing. A second set of items, covering more elementary concepts such as graphs and descriptive statistics, was used in this study as a covariate. The common cognitive measure for all three classes (items dealing with regression and hypothesis tests) was used as a measure of instructional effectiveness in this study.

Psychometric issues, such as validity and reliability, have been considered for these items. Face validity was conducted with other statistics instructors deemed exemplary. Construct validity has been carried out in various analyses over the course of development, as well as reliability assessment and item analysis. As a result, items have been removed, adjusted, or improved upon. This final bundle of items has been shown to have sound psychometric properties of consistency (coefficient alphas at least 0.80) and factor loadings consistent with the construct that the item is measuring. Each assessment per class consisted of 33 randomly selected questions from this bank of questions. Students are not allowed to keep their exam thus providing some security of the questions from semester to semester. The grade from this assessment was part of other grades used to determine the overall course grade for the class. The grading scheme for the "lecture only" and "lecture + active learning" group was identical. The grading scheme for the "lecture + active learning + team projects" class included a component on student presentation and papers as part of their grade.

A final instrument concerning team dynamics was created to measure students' perceptions of team projects. Students in the team-project group were asked to evaluate their experience with team projects during that semester. Forty-eight items were developed, and forty of these items reflected an attitudinal measure on a 5-point Likert scale. The other questions dealt with opinions on such matters as preferred group size and on locus of control in terms of project assignment. This instrument was not developed as a means of assessment but rather as a beginning explanatory consideration of the statistical results found in this study. Thus, the psychometric properties of validity (beyond face validity) were not as stringently considered as the prior measures. The coefficient alpha for the forty Likert items was 0.98.

3.3. STATISTICAL ANALYSIS

The dependent variables in this study focused on both affective and cognitive measures. The researcher felt that student attitudes toward instruction would be just as vital as cognitive measures in evaluating instructional design effectiveness. Thus, student attitudes towards the different aspects of the class and instructional approach were considered. Due to limited student identification in the baseline (lecture only) group, a multivariate analysis with both measures was not possible. Chi-square analyses were conducted to detect significant patterns of response for the affective measures. A two-factor ANCOVA design was implemented for the cognitive data. Independent variables consisted of type of instruction (lecture only, lecture + active learning, lecture + active learning + team projects) and gender (control variable). The covariate was the prior cognitive assessment of knowledge over basic statistical knowledge (graphs, descriptive statistics, and other such introductory statistics topics).

4. INSTRUCTIONAL DESIGN METHODS

Using the labels of Grasha (1996), instruction can be designed in many different ways as shown in Figure 1. This visualizes each approach as a river. The relationship of each approach can be seen by either independent, non-intersecting rivers (part a), or connected tributaries which feed into a common collection (part b). If we think of instructional approaches as such, we can consider instruction as consisting of independent approaches (e.g., lecture only (expert) or only constructivist (facilitator)), or as dependent approaches which draw upon each other for a combined approach. Whereas most might consider the first picture as unrealistically extreme of actual educational practices, the reality is that

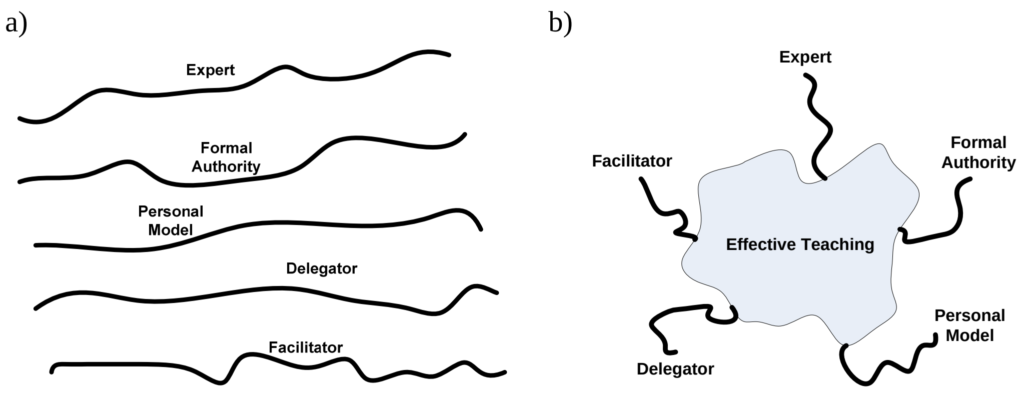

Figure 1. Independent (a) versus dependent (b) instructional approaches

some tributaries in part b might be trivial or completely forsaken (Figure 2a). Or, some may even design a particular class as consisting of only one approach (e.g., Tuesday's class is lecture, Thursday's class is hands-on application) as shown in Figure 2b. This study designed instruction that sought to favor each tributary equally within the same class. The approach as shown in Figure 1b was adopted as the instructional design of this study to test the effectiveness of balanced amalgamated approaches in both the understanding and attitudes of students. The details for each approach are presented, followed by a discussion of the statistical analysis of the relative effectiveness of the instructional approaches.

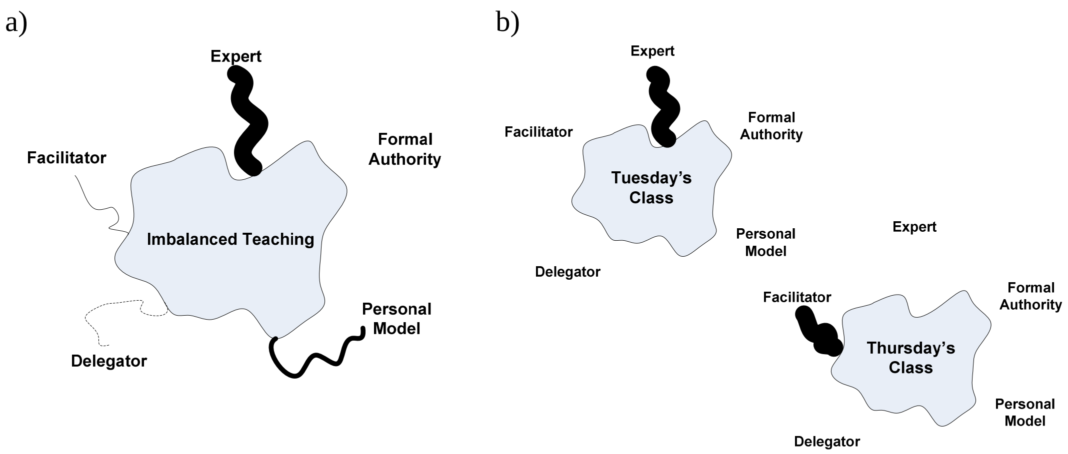

Figure 2. Examples of imbalance in instructional approaches

For this study, three instructional methods are compared: traditional lecture, mini-lectures with in-class activities, and mini-lectures with both in-class activities and team projects. The classes were all taught by the same instructor in different semesters. The instructor had ten years of experience teaching graduate level statistics courses.

4.1. "LECTURE ONLY" CLASS

The class that comprised only lecture-based instruction contained no active component or teamwork. Each class consisted of 45 minutes of lecture, along with the time for students to ask questions. Sample problems were demonstrated in class, yet the students were never involved in either the process or data collection (i.e., they were passive learners).

4.2. "LECTURE + ACTIVE LEARNING" CLASS

For the classes with in-class activities, the instructor still provided instruction, but only in short segments. A general setup for each class meeting involved small lectures with short instructional elements (5 to 10 minutes) followed by active application of the knowledge (5 to 15 minutes). Each activity was discussed afterward in class, before the next small lecture began. Thus, for a 50 minute class, a typical meeting consisted of three mini-lectures, along with three direct applications of the knowledge learned (typically in teams). This is illustrated in Figure 3.

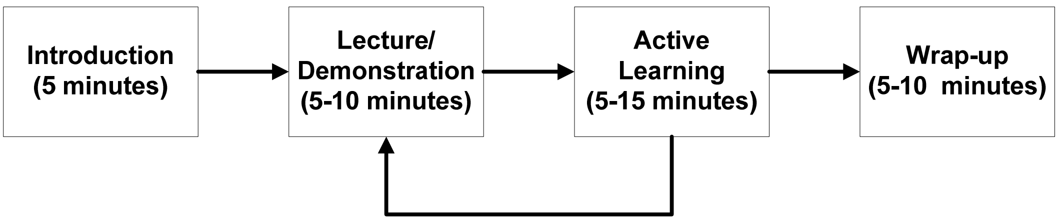

Figure 3. Class structure with active learning emphasis

This approach was modeled after one of the few textbooks that incorporates active learning within the text (Aliaga & Gunderson, 2003). From this perspective, a mixture of traditional lecture and active learning is incorporated. An example of this approach in a worksheet is presented in Appendix A. Immediately after learning new concepts or ideas, students are presented with problems (often real situations) to apply that knowledge in individual activities or as teams. For example, after learning about stratified sampling, students then split up into teams and take a stratified sample of their particular team. This allows for more immediate feedback as to how a student is assimilating the information. In addition, this approach allows a student to see real-life examples on their own. Because of the nature of this approach, however, students do not have the time to devote to more advanced statistical methodology such as sampling designs. Thus, this research also considers the addition of team projects to this paradigm.

Worksheets were incorporated and made available to students via a course webpage. The worksheets contained material that the instructor first introduced in the "mini" lecture. Students completed the worksheets after each mini lecture either individually or in groups (depending on the activity of the worksheet) during class. The activities were designed so that the amount of individual versus group-related activities approximated a 50/50 proportion over the entire semester. However, on a given day of instruction, this proportion was not always 50/50. For half of the group activities, students were allowed to work with their neighboring students (which was helpful in larger classes). Predominately, these groupings were fixed for the entire semester. The other half of group activities were done so that students congregated in new ways around the classroom. This was sometimes accomplished by instructor assignment or students randomly assigning themselves to a group (using random number techniques and areas assigned number labels), or in just pseudo-randomly walking around the class to find a group (which can be too time consuming).

4.3. "LECTURE + ACTIVE LEARNING + TEAM PROJECTS" CLASS

The last mode of instruction involved a class that combined the active-learning element previously mentioned with team projects. Students were split up into groups of four to five students as chosen by the students, and assigned a project from a list of projects the instructor had assembled. Teams were allowed to modify projects, with instructor permission. However, only one team modified a project. The modification only changed the population of the study for the particular project. In order to encourage student involvement, many of the projects were devised from more "sensational" ideas that made the presentation of the results interesting to students. For example, one of the projects in the "regression" unit focused on surveying students to see whether there was any correlation between GPA and the number of alcoholic drinks consumed per week. Although such a question is highly dramatic, the results provide a memorable discussion into the ideas of correlation, and the problem of causation. From there, a short discussion of response bias is often appropriate. Students were required to stay in the same team the entire semester. The in-class group activities utilized teams whose compositions differed from those of the team projects. Inevitably, students from the same team might be members of the same in-class groups, yet no team group was contained within the groups for in-class activities.

The initial focus of this research centered on projects that involved educational settings. This, however, proved more difficult than earlier imagined. In particular, studies on young children or teenagers often require special permission and take much time to setup. Projects needed to be devised that did not demand too much of a student's time. Although educational data sets are available, the purpose of this research was to involve the students in all aspects of research – from data collection to analysis. The solution in this research was to create projects that tended to be behavioral or sociological in nature. Although some projects did involve student attributes (and thus were educational in nature), most projects were forced to be generally behavioral. Four projects were given during the semester which focused on application of various topics discussed in class:

1. Data (sampling, bias, etc.)
2. Descriptive statistics (central tendency, variability, boxplots, etc.)
3. Hypothesis testing (*t* tests, ANOVA, etc.)
4. Regression (correlation, simple linear regression, multiple regression, etc.).

A listing of sample projects used is given in Appendix B. Some of these projects were modified from Smith (1998).

On a set date, students were asked to turn in a written summary of results (in APA style) and to give a presentation. As mentioned previously, research has shown that summarizing and presenting statistical results is a more demanding learning taxonomy level than simply analyzing the numbers. Because of the size of the class, presentations were randomly selected and only those teams randomly selected had to present their findings in class. This allowed for half of the class period to still involve learning units, then the last half of class was used for project presentations. The teams were asked to limit their presentations to ten minutes.

5. RESULTS

5.1. AFFECTIVE RESULTS

Comparisons were made for the attitudes of students in the various instructional treatments. First, students were asked to rate the effectiveness of the instruction. A summary of the results is presented in Figure 4. Because many of the frequencies for the "poor" and "fair" responses were zero for the classes with active learning, the responses for "poor," "fair," and "good" were combined into an "at most good" category so that the assumptions of the chi-square test would be valid. Thus, the chi-square tested the independence of instructional approach to ratings of excellence.

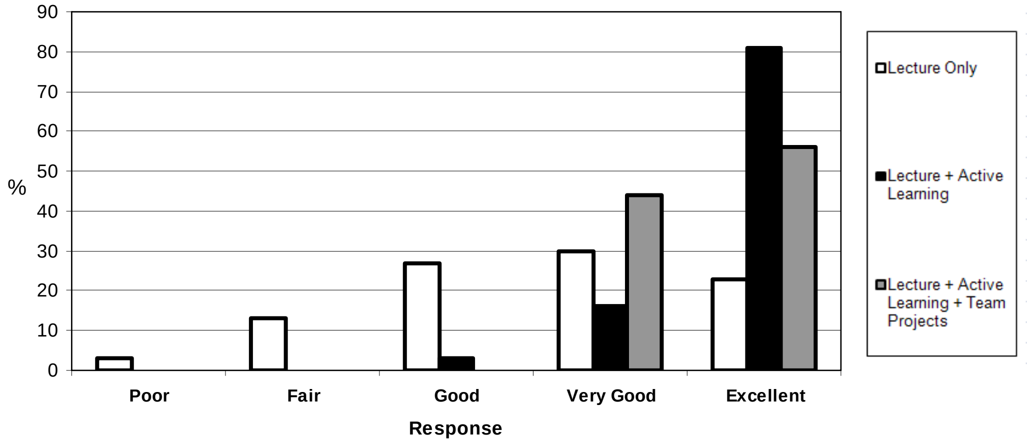

Figure 4. Communication of ideas and information

There is a sizeable difference that the active-learning component made for students' assessment of instructional effectiveness ($\chi^2(4) = 35.2$, p-value < 0.01). Whereas only 23% of students in the lecture-only class viewed the communication of ideas and information as being excellent, 81% of students in the amalgamated lecture/active learning class rated this communication as excellent. Interestingly, this high ranking did not hold when team projects were introduced into the course. For this class, the percentage of "Excellent" responses dropped to 56%. Although, the extreme satisfaction with the course ideas did not remain when team projects were introduced, it is important to note that there is a drastic positive shift in student attitude with either approach as compared to the traditional lecture approach.

Next, students were asked to rate the stimulation of interest in the course they experienced. This is an important factor because motivation in statistics classes has often been noted as a major problem by instructors. These results are summarized in Figure 5.

The results of a chi-square test were significant ($\chi^2(4) = 18.9$, p-value < 0.01). Although more students felt the communication of ideas was excellent for either the activity-based class or team-based, there was a slight drop in percentage of students who felt their interest in the course was stimulated. However, it is important to realize the great increase in student interest by incorporating active-learning components or active learning with team-based projects. For students in the activity-based class, 74% of them gave an "Excellent" rating for stimulation, as compared to just 23% in the traditional lecture class. A slightly lower, but still positive, rating (63%) was recorded for students in the team-based instructional classes.

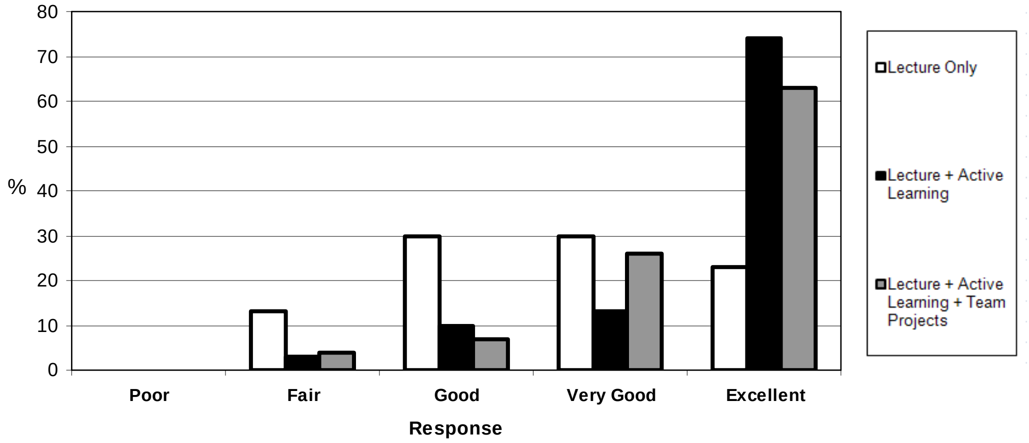

Figure 5. Stimulation of interest in the course

Students were also asked to rate how well the class structure facilitated their learning. This question was more specific than the one presented in Figure 4. The question represented in Figure 4 considered an overall communication of the class ideas. For the question on facilitation, students were asked to rate how well the instructional approach helped in learning. The results are presented in Figure 6.

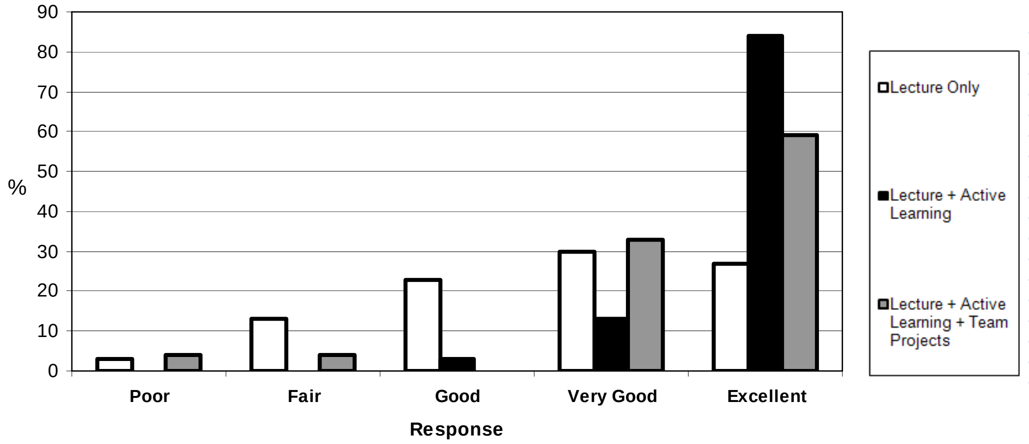

Figure 6. Facilitation of learning

As before, a much higher percentage of students in the activity-based class (84%) and team-based class (59%) rated the instructional approach as "Excellent" as compared to the traditional lecture-only approach (27%) ($\chi^2(4) = 26.1$, p-value < 0.01). Students seemed to feel much more confident with the activity-based learning (alone) than either of the other methods, although the activity + team project-based approach was favored by students over the lecture-only as well.

Finally, the overall rating of the instructor was considered. These results are presented in Figure 7. The percentage of students rating the instructor as "Excellent" rose for each teaching approach: 37% (lecture only), 90% (lecture + active learning), and 70% (lecture + active learning + team projects) ($\chi^2(4) = 24.2$, p-value < 0.01). This is expected because the question addresses more of rating of a person than course materials or instruction. Thus other confounding variables (such as friendliness of teacher) may account for the percentage increase across all types of instruction. Yet the same pattern remains in which the "Lecture + Active Learning" class is rated best by students, followed by the "Lecture + Active Learning + Team Projects" class, and lastly the "Lecture Only" class.

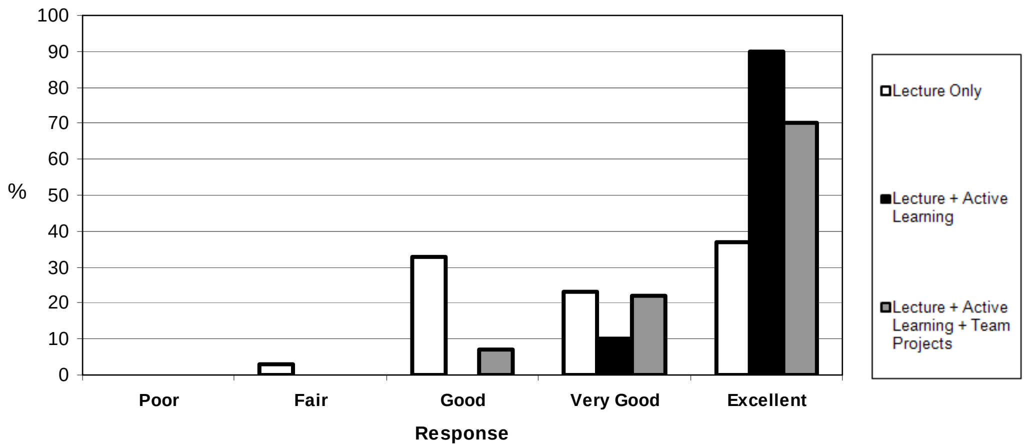

Figure 7. Overall assessment of instructor

5.2. COGNITIVE RESULTS

Assessment of student knowledge of regression and hypothesis tests was considered as the cognitive measure of the effectiveness of each instructional method. This final measure consisted of 33 questions randomly chosen from a validated and reliable bank of questions about regression and hypothesis testing ideas. A prior cognitive measure was also used: another 33 questions randomly selected from a validated and reliable bank of questions about basic statistical knowledge (graphs, descriptive statistics, and so on). Table 1 summarizes the cognitive measures for each class.

Table 1. Descriptive statistics for prior and final cognitive measures

		Prior Cognitive Measure		Final Cognitive Measure	
	n	Mean	SD	Mean	SD
Lecture Only	59	85.62	10.52	84.84	8.92
Lecture + Active Learning	44	88.64	8.81	91.55	6.03
Lecture + Active Learning + Project	47	83.51	9.10	89.20	9.90
Total	150	85.84	9.75	88.17	8.93

An initial check of assumptions revealed possible problems with outliers and normality (Figure 8). Because the cognitive outcomes were measured in such a way as to be considered a proportion, the cognitive measures were transformed using an arcsin transformation as suggested by Neter, Kutner, Nachtsheim, and Wasserman (1996). No outliers remained after transformation. Using these transformed variables, the assumptions of normality of sampling distributions, linearity, homogeneity of variance, homogeneity of regression, and reliability of the covariate were found to be satisfactory.

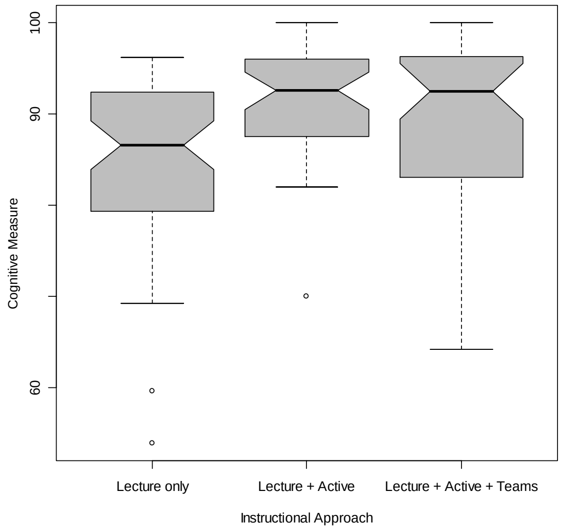

Figure 8. Boxplots of final cognitive measure by instructional methods

After adjusting for prior cognitive abilities, final cognitive assessment varied significantly with type of instruction ($F(2, 143) = 18.925$, p-value < 0.001). The ANCOVA results are summarized in Table 2. The strength of the relationship between adjusted cognitive final measure and type of instruction was moderate with partial $\hat{\eta}^2 = 0.209$. The adjusted non-transformed marginal means, as shown in Table 3, indicate that the highest final cognitive measure was for the class that had lecture, active learning, and team projects. The lowest final cognitive measure was for the class with only the traditional lecture. A post-hoc test revealed significant differences between the "lecture + active learning" approach and the "traditional lecture," as well as between the "lecture + active learning + team project" approach and the "traditional lecture." There were no significant differences between the "lecture + active learning" and "lecture + active learning + team project" approaches. Based on these results, graduate students who are more actively involved in their learning (whether through in-class activities or in-class activities and team projects) have significant gains in cognitive understanding, on average.

No statistically significant differences between males and females were found, nor was there a significant interaction effect between instruction type and gender. For gender, partial $\hat{\eta}^2 < 0.001$ indicated an almost non-existent relationship between gender and final cognitive measure. For the interaction, partial $\hat{\eta}^2 = 0.01$ indicated a weak relationship between adjusted final cognitive measure and combinations of gender/instructional method.

Table 2. Analysis of covariance of final cognitive measure

Source of Variance	Adjusted SS	df	MS	*F*
Type of instruction	1.542	2	0.771	18.925*
Gender	0.001	1	0.001	0.018
Interaction	0.059	2	0.029	0.721
Covariate (adjusted for all effects)				
Prior cognitive measure	4.589	1	4.589	112.634*
Error	5.826	143	0.041	

*p-value < 0.01

Table 3. Adjusted and unadjusted mean cognitive measure for three designs of instruction (untransformed)

Type of Instruction	Adjusted Mean	Unadjusted Mean
Lecture Only	84.92	84.84
Lecture + Active Learning	89.58	91.55
Lecture + Active Learning + Team Projects	90.91	89.20

5.3. POST-HOC QUESTIONNAIRE OF TEAM DYNAMICS

The addition of team projects did not significantly improve student attitudes or the cognitive measure as compared to the class that only had in-class activities. This is surprising as students were often heard discussing the results with other students, and the researcher felt that peer instruction was occurring more often than in previous semesters without team projects. To understand this phenomenon better, students who were exposed to both active learning and team projects were asked to describe their learning experiences with the team projects. These results differ from earlier questions in that the goal of these questions was to isolate student attitudes specifically on team projects and not on the active-learning component of the course. The results for the overall experience with team projects are presented in Table 4. Overall, 87.3% of the class reported having a positive experience by inclusion of team projects. A small minority (4.2%) had negative experiences with team projects. In reviewing the reasons why, it was noted that one of these individuals did not feel respected by the other team members, and another student felt frustrated by the lack of work from some team members.

Table 4. "What was your experience of team projects in this class?"

	Frequency	Percent
Very Negative	1	2.1
Negative	1	2.1
Undecided	4	8.5
Positive	28	59.6
Very Positive	13	27.7

Students were also asked how the team projects helped in the learning of the material. The summary of these results is presented in Table 5. The inclusion of team projects was meant to make the statistical content more meaningful to students. In this case, 82.9% of students felt that the projects helped them understand the material better. Interestingly, this percentage was less than the percentage for the overall experience. Slightly more students had a positive experience with team projects, with more students not feeling that the projects helped them. Yet, overall, inclusion of projects did seem to help.

Table 5. "Did team projects help you understand course materials?"

	Frequency	Percent
Strongly Disagree	3	6.4
Disagree	5	10.6
Undecided	0	0.0
Agree	27	57.4
Strongly Agree	12	25.5

Teams were set at four to five people at the beginning of the semester. Students were asked what group size they preferred working in. These results are presented in Table 6. Nearly half the subjects indicated that a three-member group would have been preferred over a larger group. The optimal group size for most students was three to four people, with most students feeling better about a 3 member group.

Table 6. "What team size do you prefer to work in?"

	Frequency	Percent
2 person team	7	14.9
3 person team	23	48.9
4 person team	16	34.0
5 person team	1	2.1

One potential problem with working in teams is that students do not always participate. Students in this sample indicated that this was sometimes a problem in their team projects (Table 7). Over one-third of all responses (36.1%) indicated that some teammates consistently failed to produce the results required of them in a timely manner. Obviously, this appears to be a problem with any team activities and should be addressed.

Table 7. "Did any team members fail to produce results in a timely manner?"

	Frequency	Percent
Don't Know	1	2.1
Never	19	40.4
Rarely	10	21.3
Sometimes	9	19.1
Often	8	17.0

As a final measure of the "lecture + active learning + team project" treatment, students were asked if more emphasis should be given to the projects in class (e.g., write-up of discussions, examples from the literature, more computer emphasis). This question was needed to ascertain whether the balance of lecture, active learning, and cooperative teams was good. These results are presented in Table 8. The results were mixed. More than one-third of the class (42.5%) felt that more emphasis should be placed on the cooperative learning element.

Table 8. "Should team project be emphasized more in class?"

	Frequency	Percent
Strongly Disagree	2	4.3
Disagree	9	19.1
Undecided	16	34.0
Agree	16	34.0
Strongly Agree	4	8.5

6. DISCUSSION

6.1. CONCLUSIONS

The inclusion of student activity (whether in-class activities or in-class activities combined with team projects) was seen to have a major impact upon graduate students learning of statistics. This effect was not only seen in specific cognitive measures, but also in the students' perceptions and attitudes toward the course. By doing hands-on activities, whether in class or outside of class in team projects, students appeared better able to make real connections to the knowledge they were learning. This, in turn, should provide more motivation to learn.

In fact, by getting away from a pure lecture approach, significant gains in cognition of course content and attitudes appear to be possible. Similar to Keeler and Steinhorst (1995), this study included a typical lecture in addition to innovative instructional models. Instead of abandoning a method that has worked somewhat in the past (especially in graduate-level statistics education), this research has attempted to incorporate other proven instructional techniques to create a "balanced amalgamated" approach to teaching statistics to graduate students. In addition to Keeler and Steinhorst's approach, this study also considered varying methods of active learning in teaching along with a team-based cooperative learning model. And though the results of this study are not conclusive about the use of team projects, more active involvement by students does appear to be the better way of approaching statistical instruction for graduate students.

The optimal structure of a class that emphasizes more student activity is unclear. In this study, the biggest impact came from combining mini lectures with in-class activities. Adding team projects diminished this impact somewhat. Yet this may be due to many things other than the non-effectiveness of team projects. The addition of team projects (along with active in-class activities) did provide significant increases in cognitive measures over a traditional lecture approach. The diminishing effect of teams versus a pure in-class activity approach seems to be influenced heavily by group dynamics. Some of the groups in the study had personality clashes. One student actually asked to be moved to another team because of personality issues. In addition, almost one-third of the class mentioned the timeliness of other team members as being a detrimental factor. Finally, team projects do require more work. This may have an impact on team effectiveness.

6.2. LIMITATIONS

One of the major limitations of this study is the presence of confounding effects and potential sampling bias. The same teacher taught all three classes, and students were not randomly selected to participate nor randomly assigned among the three treatments. Though prior knowledge was included as a covariate, higher scores on the pretest could indicate a more positive disposition of students entering the course affecting their attitudes and learning gains. Replication of this study with other teachers would be beneficial, as well as with departments other than Education. This research always assumed that a lecture approach was part of any class. No teaching paradigms were considered where a class setting whould be purely active or cooperative. The use of team projects along with mini lectures with no active-learning component, the use of only active learning, or the use of team projects as the sole instructional approach was not considered. A course that spends more time on team projects may see a bigger team project effect. Such a class would be a "practitioner" course in that the total emphasis is on application of statistics and not so much theoretical knowledge (as provided in a lecture). This type of course was not considered in this study. However, to know the impact of these instructional elements fully, studies should be conducted that look at an approach using these methods in teaching statistics.

6.3. SUMMARY

This research attempted to answer a central question: Does a structure incorporating more active student involvement help graduate students learn statistics? The answer based on this study does appear to be "yes." Still, the question of what combinations of instructional design to use remains unanswered. Though incorporating both active learning and team projects with lectures showed more positive effects than a lecture only approach, there was no statistical difference between that approach and the "lecture + active learning" approach. Furthermore, from this instructor's experience, student attitudes are often better when the instructor was more in control of the active component. Perhaps the inclusion of team projects shifts the locus of control too far for graduate students? Such consideration is worthy of future study. Regardless, this study suggests that any active component in a graduate-level statistics class makes it better, both affectively and cognitively.

6.4. IMPLEMENTATION STRATEGIES

My own experience with incorporating active learning in teaching has always been successful. When I incorporated the active component into the class, I could see an immediate effect upon students. In previous semesters I had tried a more constructivist approach to teaching and felt that the class was not successful. Based on that experience, the inclusion of some form of lecture component seemed necessary. This amalgamated approach took away many of the fears I had in incorporating the ideas. By having small active-learning components in the middle of lecture components, I could see whether students really understood what I had just shown them. Also, this builds confidence in students. Theresa, the student mentioned earlier, was one such example as she was in the "lecture + active learning" group. By the end of the second week, she expressed to me how she was really enjoying the class and how it was not nearly as bad as she had originally thought. I cannot imagine teaching without some form of active learning now. I have applied this same teaching paradigm to more advanced statistical classes with similar results of improved morale, attention, and assimilation of information.

The inclusion of team projects posed mixed results, however. First, there was more of a struggle with how to allocate class time for such matters. Although including active learning would seem to present the same challenge, team projects always presented the major challenge in time. For me, team dynamics was a factor that grew tiring to oversee. I still see the benefits in team projects, yet it seems that I see little difference in performance by leaving it out and using active components in class (which still involve working with others). This is a matter of further investigation for me. Of particular interest would be studying the different outlooks and motivations for undergraduate versus graduate students in regard to team projects and team learning.

To successfully implement such a change in a classroom requires a radical shift in perspective for most instructors. Thus, I offer the following suggestions that I have learned over the past 10 years of trying to incorporate such designs in my own classes:

1. *Review learning and cognition materials* – Although direct research (like this study) is obviously important to consider, I have found that there is a wealth of information about such matters in the learning and cognition domain. One would also greatly benefit by finding someone who specializes in this field and discussing matters with them. Though I have not always incorporated their ideas or techniques, I have often come away from such conversations with clarity of thought and purpose. The

statistical education domain would greatly benefit if there were more collaborations in research with learning/cognition researchers, not to mention how beneficial textbooks might be if such collaborations extended into authorship. As mentioned previously, most current graduate statistical textbooks ignore these new teaching methods altogether.

2. *Study effective teaching models* – There is a wealth of ideas often right on our own campuses about effective teaching models. I occasionally ask other faculty members to let me sit in on their class for my own personal benefit. In my younger years, I would too often want to emulate the habits and mannerisms of those I admired or respected. I remember the first time I saw Jaime Escalante in the *Stand and Deliver* famed movie. After seeing him in action, I wondered if I should dress up in costumes and use props in my classes, or have my classes do chants in the classroom. Yet, in time, I have seen that I need to become a unique expression of these effective techniques I have learned. I believe this is important because at times I have rejected whole approaches in teaching because I could not see myself implementing them in the same manner. For example, I have seen instructors using a "game" for an in-class activity, and had inner struggles with incorporating this particular expression: "That may work for an undergraduate class, but this is a graduate class on Bayesian analysis! Won't this seem 'childish' to the students? Even if I were to try it, how can I come up with a game in this class?" What I have learned is that I may not always prefer or use a particular expression, but I can still strive to incorporate the spirit of the expression (e.g., in this case by creating active components that are interesting and fun to students).
3. *Start small* – If you are new to active-based learning (whether in-class activities or team projects), it might be beneficial to incorporate this new learning style in small ways until you are comfortable with the approach. Consider the worksheet in Appendix A. One suggested approach is to design such a worksheet for a particular class lecture, and have students work on it for a few minutes in the middle or end of class. The key to incorporating such active-based learning is to keep the activities short (average of 5-10 minutes). Some activities may require longer periods of time to complete, possibly up to 30 minutes. But those activities should be the exception, not the rule. Take one lecture and add one active component to it. Do this over a period of time and increase the amount that you use until you feel you have reached a balance that works for you and your teaching style.
4. *Plan and delegate* – One concern in using active learning along with lecture is anxiety about covering the breadth of material that is covered in a lecture-only format. Though this concern might have some degree of merit, I have found in my own experience that this is not the case. However, successful implementation does require some degree of thought and preparation. I have personally found that I save time while lecturing by not spending as much time working through an example in class. Before, I would spend a lot of time in order to make sure students understood every facet. Now, I realize that any part they don't understand will be magnified in the active component which follows my example. Also, there are often concepts that can be learned in the active component rather than taught in lecture. This provides a unique form of constructivist learning and is easy to implement within such a structure. Whereas there is much discussion of the fatigue that faces students in a long lecture, I think a neglected area of research is the fatigue that occurs with an instructor. I find by using mini-lectures that I stay focused on my teaching and can cover the same material in less time.

5. *Be active yourself* – While students are working on an activity, consider walking among them and observe their progress. This can be beneficial for many reasons including making sure students are working on the task you have asked them to work on. Also, some students may not volunteer problems they are having in front of the entire class and this provides you with an opportunity to see particular problems they may be having. Obviously with moderate (as in the case of this study) to large classes, it might be impossible to go to each person or group in the allotted time for the activity. In this situation, if you have more than one activity for that day, consider randomly moving around during each activity. In my case, I will mentally cluster students in various parts of the room and randomly choose clusters to visit during an activity. I strive to visit each cluster at least once during a class.
6. *Don't confuse noise for control (or lack of)* – Students in my classes are often quiet during the first few weeks of active components, perhaps because it seems such a foreign approach for a mathematically-based class. Yet over time, they usually embrace it heartedly to the point that the classroom is filled with talk and laughter. For someone coming from a lecture-only format, this can seem threatening, as if you have lost control of the class. Always keep in mind that you are actively engaging your students and helping them master the material. Some of my classes have been so engaged that it has taken me quite a few seconds to regain their attention. At first this would bother me greatly to the point of questioning my new approach. Now, I can usually regain control of the class easier by simply talking to them while moving around among them and simply saying, "OK, let's talk about something that I see you all are having a problem with." Others may wish to utilize visible clues that are discussed earlier with the class (e.g., turning the lights on and off a few times). If you are new to this teaching style, do not let such matters deter you from exploring this "brave new world."

6.5. FUTURE RESEARCH

One possible extension of this study is to adjust the way in which team projects are done. Some students wished for more freedom in the choice of their projects. A future study could consider this effect. Smaller group sizes should also be considered as this may reduce some of the tensions in groups found in this study. Also, an approach in which the instructor supervises the teams more vigorously might prove valuable and eliminate the slightly diminishing results from team projects. The approach taken in this study was not as rigorous because the instructor assumed that graduate students would not need as much oversight. This study considered only the basic-level statistics course for graduate students in order to serve as a bridge with similar research in undergraduate studies. Further studies applied to advanced courses (e.g., regression, multi-level models, structural equation modeling) should be investigated. Tying together affective and cognitive measures in a unified statistical analysis, as well as tracking changes or growth over time in longitudinal studies, would also be beneficial.

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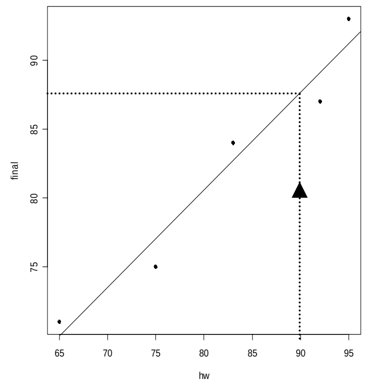
APPENDIX A: AN EXAMPLE OF ACTIVITY-BASED IN-CLASS LEARNING



The least square regression line for homework score (x) and final exam score (y) is $\hat{y} = 23.87 + 0.71x$. The slope of b = 0.71 indicates that if homework grade were to increase by 1-point, we would expect on average for the final exam grade to increase by 0.71 points. The estimated y-intercept (a = 23.87) indicates that a student who made a 0 on their homework grade would have a predicted final exam grade of 23.87.

Let's pretend we have a student who has a 90 homework grade, and we wish to predict their final exam grade. One way to do this is to use the scatterplot and our least squares regression line. If you find 90 on the x-axis and trace up to the regression line, you can look across and get a predicted value for y (final grade) of around 87 or 88. Another way to do this would be to plug the value x = 90 into the regression equation: $\hat{y} = 23.87 + 0.71(90) = 87.77$.

Your Turn!

Assume that the hours a student watches television and their test grade are linearly related. The least squares regression line was calculated as $\hat{y} = 95.3 - 1.54x$, where y is the test grade and x is the number of hours a student watches television during a week.

(a) Interpret the value of the estimated slope b = –1.54.

(b) How would you interpret the y-intercept of a = 95.3? Does the interpretation make practical sense in this instance?

(c) What would you predict the test grade to be for a student who watches 5 hours of television on a given week?

(d) What would you predict the test grade to be for a student who watches 70 hours of television on a given week?

(e) Why do you think your answer to part (d) was so inaccurate?

APPENDIX B: SAMPLE OF TEAM PROJECTS

Data

1. It has been reported that college students are pessimistic about the future of the social security system. How would you survey students at our school to learn more about how confident they are that they will receive substantial social security checks when they retire? Develop a short questionnaire, and explain exactly how you would select the students to be questioned.
2. Ask 25 randomly selected people this question: "Karl Marx said, 'Whenever a form of government becomes destructive of these ends, it is the right of the people to alter or to abolish it.' Do you agree?" Now ask 25 randomly selected people this question: 'The U.S. Declaration of Independence says: 'Whenever a form of government becomes destructive of these ends, it is the right of the people to alter or to abolish it.' Do you agree?" Compare your responses.
3. Working either in pairs, or alone, go to a well populated area (like a shopping center). Randomly select people and ask them if you can do a quick survey for your statistics class. If they say yes, ask them the following two questions: "Do you believe in cloning? Do you believe in life-saving organ replication?" Record the answers for at least 50 people. Summarize your findings.
4. Working either in pairs, or alone, go to a well populated area (like a shopping center). Randomly select people and ask them if you can do a quick survey for your statistics class. If they say yes, ask them the following two questions: "Disposable diapers account for 6% of landfill waste, whereas yard wastes and plastic bottles account for 40% of yard wastes. In light of this fact, do you think it is fair to ban disposable diapers?" Record the answers for at least 30 people. Summarize your findings. Then rephrase the question to be more neutral. Redo another random sample of 30 people. Compare the response to the original question. Comment.
5. Should kids between 12 and 18 have cell phones? Conduct a survey of local residents to find their opinions. Be sure to ask both adults who have wireless service and those who don't. Report any general findings, and also see what general differences in opinion exist for adults who use cell phones and those who do not. Be sure to report on your sampling method (whether good or bad), possible bias in the survey, and ways the study could be improved. Try to get about 50 subjects if possible.
6. Conduct a survey of students (other than your statistics class) on the subject of the internet and cheating. In particular, design and administer a survey that asks several questions about whether students have used the internet and committed plagiarism. Make the survey anonymous, and stress that to students. What effect do you think such a loaded question might have on the response? Report your findings in a general sense? How often do students tend to cheat if they do at all?

Descriptive statistics

7. Sample a group of students in regard to a fictitious question (for example, "Do you support the rebel efforts in Alfa-Centuri?" … Alfa-Centuri does not exist.). Feel free to use my question or come up with one of your own. Develop a survey with a few factual questions and stick this fictitious question among them. Survey at least 30 students or people. Try to get a mixture of males and females.

Compare males and females using some of the graphs and summaries discussed in class.

8. Select teachers (you cannot select me ☺), and record the number of times that this teacher says “Uh” or “Um” during the class period. Try to obtain at least 10 teachers, and if possible at least 5 male and female. Summarize the results numerically by teacher. Do a side-by-side boxplot comparing the gender of the teacher. What differences did you find? Which gender had more variability? [Note: Creating boxplots with so few data values becomes a class discussion point.]
9. Post a sign on the main entrance to a campus building requesting the use of a less convenient entrance; for example, “Please use the door on the north side of building.” From an inconspicuous location, observe how many people ignore the sign and use the main entrance and how many people do not use the main entrance. Compare the behavior of students and professors or males and females. Try to pick a building and time when traffic is light, so that large numbers do not try to enter simultaneously. Try to get at least 50 in your sample.

Hypothesis testing

10. Do more expensive cookies taste better than less expensive cookies? Choose two brands of cookies that appear to be similar but cost quite different amounts. Ask at least 40 people to taste an unlabeled cookie from each brand and to rate each cookie on a scale of 1 to 10; use a matched-pair test to assess the statistical significance of your results.
11. Do males over-exaggerate their heights? Take a random sample of at least 50 males. Ask them their heights. Then measure their heights. Do a matched pairs *t* test to see if males tend to over-exaggerate their heights.
12. Do males and females differ in terms of the number of traffic tickets they get? Or in the number of accidents they’ve been involved in? Do a survey of at least 25 males and 25 females. Compare each gender on both issues using a 2-sample *t* test at a 5% significance level. Are there any differences?
13. Does a difference exist between males and females in regard to the number of hours of television they watch per week? Does a difference exist in the number of hours of video games played? Conduct a survey and test the differences between males and females on both issues at a 5% significance level using a 2-sample *t* test. Try to get at least 25 males and 25 females.
14. Is there a statistical difference in the pulse rates of smokers and nonsmokers? In particular, test that the pulse rate of smokers is higher than that of nonsmokers. Sample at least 25 from both groups. Use a 2-sample *t* test and a 5% significance level.

Regression

15. Go to your campus bookstore, and select 30 new hardcover textbooks. (Be sure to explain how these books were selected.) For each book, record the number of pages and the price. Now use a scatterplot to see if there appears to be a positive or negative relationship between the number of pages and the price. Calculate the correlation coefficient, and determine whether there is a statistically significant relationship between number of pages and price.

16. Collect data for at least 10 years on the cost of attending your college. Using years as an independent variable, perform a regression analysis to see if there is a trend in the real cost of attending this college. [Note: Adjusting for inflation can become a class discussion point.]
17. Ask at least 50 people their height, and the height of their parent (same gender). Perform a regression analysis with the student's height as the dependent variable and the parent's height as the explanatory variable.
18. Conduct a survey to see if there is a relationship between GPA and the number of alcoholic drinks that a student consumes. What type of relationship do you think would exist? Did it? You need to consider what constitutes an alcoholic drink, and must also decide what to measure for the number of drinks (oz? Containers? etc). Let GPA be the dependent (response) variable.
19. A *CNN/USA TODAY* poll conducted by Gallup asked a sample of employed Americans the following question: "Which do you enjoy more, the hours when you are on your job, or the hours when you are not on your job?" Construct a 10-item Likert scale survey (of which 5-items address satisfaction with leisure, and 5-items measure satisfaction with job), and give the survey to a random selection of 30-40 adults who work. Sum each of the 5-items to get an overall satisfaction score. Perform a complete regression analysis to see what relationship exists between leisure and job satisfaction.
20. Conduct a study to see whether there is a relationship between a student's GPA and the number of hours the student watches television each week. Perform a thorough regression analysis, and try to get at least 30 students in your survey.
21. Conduct a survey of 30-40 students where you ask them to estimate the number of hours spent on the internet (including school work), number of hours working each week (job), number of classes, and GPA. Find correlations between each of these variables. Pick two variables of interest and perform a regression analysis.
22. Conduct a study to see whether there is a relationship between a student's grade point average and the number of hours the student studies each week. Perform a thorough regression analysis, and try to get at least 30 students in your survey.