Factors Affecting Student Attitudes Toward Active Learning Activities in a Graduate Engineering Statistics Course

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Abstract - The successful use of active learning practices in a medium-to-large sized (25 – 50 students) graduate engineering statistics course has its challenges as well as opportunities. Students expect that lecture would be the dominant pedagogy, so introducing team-based activities violates their assumptions about the structure of the course. Experience in teaching graduate-level courses in statistics, validated by survey responses and observation, leads us to conclude that the majority of students, regardless of their undergraduate group learning experiences, tend to prefer to work alone or in small groups with acquaintances; the main exception is a preference for working in groups on large-scale projects. Student attitudes seem to be primarily context-dependent, and we find the main factors affecting how a particular activity is received are the scope and grading-importance of the assignment; team size relative to the amount of effort required; and team composition.

Index Terms - Active learning, graduate engineering education research, statistics, and group learning.

INTRODUCTION

“Active learning” is a category of pedagogies established as being extremely effective in engaging and maintaining student interest, thereby leading to better student performance and retention of subject matter. The literature on active learning in general is very rich and robust, and the research literature with respect to engineering has been expanding for nearly two decades. However, the vast majority of this literature addresses research and implementation of activities at the undergraduate level. We believe that active learning, especially cooperative learning with its features of positive interdependence and structured individual and group accountability, may benefit graduate student learning as well. The challenge is to procure student buy-in to these practices. Our overall research goal is to determine the academic climate in which active learning has a positive impact in graduate courses, and provide a general road map for achieving that climate.

Findings from Richards’ previous informal research on this topic include the anecdotal findings that unless mandated by the instructor, graduate students tend to participate willingly in a group learning strategy only when there is a perceived benefit in doing so; that the more students are exposed to well-conducted active learning activities at the undergraduate level, the more they are willing to accept participation in such activities as graduate students; and that faculty attitudes towards innovation in the classroom, including the use of active learning strategies, tend to trickle down to students.

The results of the first round of our formal research on the topic of graduate student attitudes towards participation in group learning activities, conducted during the Spring 2007 semester at the University of Virginia (U.Va.), are reported in [1]. We employed various forms of active learning activities in our graduate statistics courses that semester, and observed several instances of student resistance to the activities. These observations led to the development of the following theses: (1) students whose undergraduate schools encouraged teamwork as part of their culture are more likely to accept working in groups in graduate school; and (2) students are more likely to accept working in groups when (a) they can opt out of the group and develop individual work product in parallel and (b) group work is purposeful – the resulting product is graded. These theses are tested in follow-on research conducted during U.Va.’s Spring 2008 and 2009 semesters, with students in Richards’ APMA 643, Statistics for Engineers and Scientists, as subjects. Analysis of data collected through surveys, classroom observations, and informal interviews, indicates that students’ attitudes towards participation in active learning activities are primarily context-dependent. Other factors to consider with respect to attitudes towards participation in active learning activities include a student’s status in his/her program vis-à-vis qualifying exams and funding, given that stress in one area can affect performance in others.

Our goal for this research phase is to identify the factors that affect student attitudes towards participating in active learning activities. Our overall goal is to design strategies which meet with minimum resistance among students whose experience is generally with working in fairly homogeneous groups and/or who are used to an isolated, individualized mode of study.

This paper is structured as follows. First, a brief review of the literature on active learning strategies is provided. Cooperative learning is used as the example since it is a more formal, structured form of active learning. The research’s theoretical frame is developed from this base, and...
the research question and researcher positionality are identified as part of this discussion. Next, the methodology used in conducting this research is presented. We end with a presentation of results, conclusions, and direction of future work.

**Review of Active Learning Strategies**

In active learning, the learner bears responsibility for learning. It is well documented that students retain more knowledge when actively engaged in the learning process, and active learning is often cited as an extremely effective instructional strategy [see, for example, 2 - 7]. It has also proven to be a set of pedagogies that is a good fit with the preferred learning and working styles of Millennials in general and students from underrepresented populations in science, technology, engineering, and mathematics (STEM), including females, in particular [8].

Many active learning strategies involve some form of group work. Group work covers all kinds of multiple-person active instructional activities along formal – informal and structured – unstructured spectra.

At the formal, structured ends of the spectra is cooperative learning, a structured process in which team members work towards accomplishing a common goal, stressing positive interdependence, individual accountability, and group accountability. Positive interdependence is a state in which all members must cooperate to accomplish the goal; under the accountability rules, each member is individually and collectively responsible for the group’s work product [2]-[3]. Cooperative learning differs from collaborative learning, activities tending to cluster at the informal, unstructured ends of the spectra, in that the former “requires carefully structured individual accountability” [3, p. 88]. Johnson, Johnson, and Smith [4] note that in addition to clear positive interdependence between students, essential elements of cooperative learning include face to face interaction, individual accountability, emphasis on interpersonal and small-group skills. Also, processes must be in place to support a team’s review of its progress.

Smith [2, p. 198] notes the following benefits of students who are “cooperatively taught”: “longer information retention, better performance on exams, higher grades, stronger critical thinking and problem-solving skills, more positive attitudes toward the subject and greater motivation to learn it, better interpersonal and communication skills, higher self esteem, and if groups are truly heterogeneous, improved race and gender relations.”

Instructor management of active learning activities is an important factor in the activities’ success. Oakley, et al. [9] report the results of a series of surveys in 533 undergraduate and graduate engineering and computer science courses at Oakland University, involving 6435 voluntary student respondents over two years, regarding the optimal conditions under which teamwork is an effective pedagogic method for the completion of homework and project assignments. Factors resulting in satisfaction with a team experience include proactive guidance from the instructor on how to work in teams effectively, team size, and mechanisms to deal with team members who are perceived as not “pulling their weight.” Bacon, Stewart, and Silver [10] find that students learn more from good team experiences than bad ones, and that instructors are critical drivers in creating an environment in which good experiences are more likely to happen.

One domain in which the effects of active learning have been well researched is computer science. Students participating in one pedagogical instantiation, pair programming, report higher levels of confidence in their abilities than students who strategized and coded on their own [11]–[13]. The use of pair programming is also effective in countering senses of isolation and alienation experienced by many students in computer science courses, especially introductory ones [13]. With respect to the composition of pairs, Williams, et al. [14] found that students prefer to be paired with others with a perceived similar or better technical skill level; students with differing work ethics are generally not compatible, and if learning styles are known, that “sensor” and “intuitor” students seem to pair compatibly. An earlier version of this work also found that females and ethnic minorities are more likely to find their partner compatible when working in pairs of same gender, same ethnicity, or same gender and ethnicity [15].

An effective self-regulated learner can learn both independently and in teams. However, lifelong learning activities tend to occur within a team/dependent learning structure according to the research presented in [16].

**Theoretical Frame, Research Question, and Researcher Positionality**

As noted in the previous section, the use of active learning strategies correlates positively with undergraduate student engagement and retention. Undergraduate retention is understandably a topic of great interest to the engineering education community, given that the baccalaureate degree is the profession’s “gateway” degree and enrollment numbers that refuse to improve despite all the attention devoted to this problem. Overall, the demand for engineers and computer scientists is predicted to rise in the U.S by 36% by 2010, yet the number of engineering baccalaureate degrees was off in 2004 by 20% from the peak number in 1985. And the national retention rate of engineering undergraduates to graduation, as of 2006, is 48% [17]. The same level of attention is presumably not given to the study of graduate engineering student retention; after all, it’s presumed that these students will be able to work as engineers if they leave their programs since they already have their baccalaureate degree. We submit that this assumption should be re-examined. For example, graduate programs are one means of developing engineers from non-traditional students [18]. With the demonstrated need to grow the profession, we feel it would be short-sighted to close down any transformational avenue.

As stated in the Introduction, our goal for this research phase is to identify the factors that affect student attitudes...
Our research question is, therefore: for a given task, what factors do we need to consider in designing a group learning strategy that meets with the least resistance from students?

Our work is primarily influenced by the qualitative analytic tradition articulated and popularized by [19]; it is also influenced by qualitative analysis methods of [20]. In the former, the overall goal of research is the description and explanation of patterns of relationships among social phenomena; in the latter, the overall goals of research include the following which fit best with our research agenda: discovery of universals through concrete particulars, improvement in educational practice, and the identification of specific causal linkages. The dominant positionality is post-positivism, given our methodology, which is heavily reliant on surveys; our inquiry aims to explain observed student attitudes toward active learning work and then support positive attitudes and control negative ones through appropriate strategies.

**METHODOLOGY**

The main research periods are the Spring 2008 and 2009 semesters at U.Va. The primary research site is Room 339 in the Mechanical and Aerospace Engineering Building (MEC) in the School of Engineering and Applied Science section of U.Va. APMA 643 meets three days a week. The class period is fifty minutes.

A mixed methods approach is used in conducting this research. Qualitative and quantitative data regarding student attitudes towards participation in group learning strategies are collected through surveys and validated through unstructured, informal interviews. No anonymous feedback, an anticipated source of data, was left by students through the course web site.

The surveys collect basic demographic data to help us determine if there are any differences among membership groups with respect to attitudes: gender, major, and degree program, and, in 2009, ethnicity/nationality. In 2008, there was not sufficient diversity in the class to support meaningful, statistically significant inferences regarding the effect of student ethnicity on their attitudes towards participation in group learning activities. Data representing attitudes towards active learning activities are collected using Likert scales and open-ended questions.

The other main source of data is observation of classroom activities. Richards serves as a participant observer and Donohue as an informed observer during the semester. We validate each other's observations.

Throughout the analytical process, we know that we need to keep in mind essential differences between undergraduate and graduate student populations in engineering, differences that may explain why graduate students are reportedly more reluctant to accept working in groups. Obviously, graduate students are older and more experienced than undergraduates, and therefore perhaps less likely to need social and psychological support from a team to complete a task. Also, graduate students tend to have personality traits that enable them to survive, if not thrive, in a culture that requires solitary study and independent work for long periods of time. Next, consider the cultural composition of the two student populations from a citizenship point of view. Americans dominate the undergraduate student population in U.S. engineering programs and international students the graduate population. Gibbons [21] reports that 6.7% of baccalaureate degrees in engineering were awarded in Academic Year (AY) 2007 to international students, a percentage that remains fairly steady over the eight academic years reported. In the same academic year, 38.7% of the master’s and 61.7% of the doctorates in engineering were awarded to international students. In AY 2008, international students are 4.1% of the undergraduate student population and 38% of the graduate student population at U.Va.'s School of Engineering and Applied Science [22]. Cultural and linguistic barriers to effective teamwork – on both sides – are thus more likely to exist in graduate courses, leading, we theorize, to students’ possible disinclination towards working in heterogeneous groups. A review of the class roll shows a 70%/30% American/international split in the student population for 2008 version of APMA 643 [23] and a 52%/48% American/international split in the 2009 version [24]. The dominant countries of origin for international students are China and India.

These demographic considerations also feature prominently in the determination of whether the reported results for this particular set of graduate engineering students are generalizable. We address this concern by determining the students’ representativeness with respect to prior classes under the assumption that if this class’ profile is similar to that of past classes, then the results are more likely to be generalizable – realizing, of course, that demographics do not necessarily drive attitudes. Richards’ review of past class rolls and related notes support our conjectures that these classes’ profiles fall within parameters established through experience. Richards has been teaching APMA 643 since 1985.

**RESULTS**

1. Observations

Group learning activities occurred in half of the class periods with opportunities for group learning activities to occur in both semesters. The dominant group learning activity is groups informally formed by students using nearest neighbor method working on ungraded examples in the text or presentation for fewer than 5 minutes. Since working in groups under this scenario is encouraged but not mandated, there will always be students working alone – roughly, about a third of the class in each semester. We did not seek information on student participation in active learning activities outside of class, such as study groups. Table I is a summary of the observed group learning activities. Note that the number of classes in which both formal and informally assigned groups were employed increased in

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>APMA 643 GROUP LEARNING ACTIVITIES – SPRING 2008 AND 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008</td>
</tr>
<tr>
<td></td>
<td># and %</td>
</tr>
<tr>
<td>Regular Class Periods</td>
<td>42</td>
</tr>
<tr>
<td>Suspended Class (MLK Holiday)</td>
<td>1</td>
</tr>
<tr>
<td>Tests and Test Review Sessions</td>
<td>5</td>
</tr>
<tr>
<td>Class Periods with Group Learning Activity Opportunities</td>
<td>36</td>
</tr>
<tr>
<td>Instructor Assigned Teams, Graded Assignment 20 - 50 minutes</td>
<td>2</td>
</tr>
<tr>
<td>Instructor Assigned Teams, Ungraded Assignment 20 - 50 minutes</td>
<td>1</td>
</tr>
<tr>
<td>Student Formed Teams, Ungraded Problems &lt;= 5 minutes</td>
<td>15</td>
</tr>
<tr>
<td>1 Exercise per Class Period</td>
<td>8</td>
</tr>
<tr>
<td>2 Exercises per Class Period</td>
<td>4</td>
</tr>
<tr>
<td>3 Exercises per Class Period</td>
<td>3</td>
</tr>
<tr>
<td>Class Periods with No Group Learning Activity</td>
<td>18</td>
</tr>
</tbody>
</table>

Other observations from the Spring 2008 semester include:
- Students in the same department tended to sit together, which results in that cohort forming one large group during informal active learning activities.
- There was a cohort of students who regularly did not attend class – primarily, international students majoring in computer science.
- There were approximately 25 students who came to class on a regular basis (out of a final enrollment of 33, for 75% average attendance).
- Once student seating was established, students rarely changed their seats, resulting in the same students working together in informal groups formed using the “nearest neighbor” method.

In general, the Spring 2009 class activities have similar patterns with respect to student seating, arrival, and attendance. Student attendance averages 79% for classes with no scheduled grading activity, such as tests and quizzes. Additional observations include:
- Most students worked alone at the beginning of short ungraded problem activities and conferred with a nearest neighbor regarding results with the exception of one group of four USA females and one group of four to five Chinese students (one female and three to four males, depending on attendance).
- At the beginning of the semester, international students would physically move to be with a compatriot for informal active learning activities featuring student-formed teams.

For both semesters,
- There would always be students, both USA and international but predominately male, who worked alone during informal active learning activities featuring student-formed teams.

II. Demographics

Basic student population demographics for both semesters are provided in Tables II and III. The data in Table II are from the initial survey administered in February, 2008. Additionally, recall that data on ethnicity/nationality were not elicited from the Spring 2008 cohort.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>BASIC DEMOGRAPHICS – SPRING 2008 COHORT (N = 31)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Program</td>
</tr>
<tr>
<td>Female</td>
<td>MS</td>
</tr>
<tr>
<td>Female</td>
<td>PhD</td>
</tr>
<tr>
<td>Male</td>
<td>MS</td>
</tr>
<tr>
<td>Male</td>
<td>PhD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>BASIC DEMOGRAPHICS – SPRING 2009 COHORT (N = 42)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Program</td>
</tr>
<tr>
<td>Female</td>
<td>MS</td>
</tr>
<tr>
<td>Female</td>
<td>PhD</td>
</tr>
<tr>
<td>Male</td>
<td>MS</td>
</tr>
<tr>
<td>Male</td>
<td>PhD</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* - not all students completed surveys

All students in the Spring 2008 cohort are taking the course to fulfill their program’s math requirement, and all report taking an undergraduate course in statistics via an informal “show of hands” during the first class session. Only three students were not in their first year of graduate studies. This fact is a critical one with respect to the development of positive attitudes towards participation in group learning activities, since first year graduate students face other program-related stressors such as preparation for gatekeeping events, such as qualifying exams, which may have an impact on their attitudes concerning participation in active learning activities. Donohue noted resistance to
attitudes with respect to group work in general and in conjunction with APMA 643. Responses are elicited using a Likert scale of 1 = strongly disagree to 5 = strongly agree. Mean and median response values are presented in Table IV. A review of the values indicates, with few exceptions, that the medians are typically in the “neutral” to “agree” section of the response spectrum for both genders. However, the means indicate that females are more likely to be receptive to working in groups than males. One implication may be that we would want to have mixed gender teams under the assumption that the females’ more positive attitude might neutralize the males’ less positive attitude towards group work. Another implication is that these respondents prefer to work alone and in groups, providing support for the conclusion that attitudes towards participation in group learning activities may be dependent on context: when the activities occur, what the deliverable is, and who determines group membership. Anecdotal evidence also supports this conclusion: for example, complaints about cooperative learning activities to review homework answers early in the Spring 2009 course stemmed primarily from students’ perception of the mismatch between the effort to form assigned teams and task triviality.

CONCLUSIONS AND FUTURE WORK
Based on the above analysis and the preliminary conclusion that student attitudes towards group learning are context-dependent, a conclusion with respect to our research question is to use the scope and grade-importance of the assignment to scale team size, method of assignment, and composition. Given the above results, tasks with a short completion time and low to no impact on the final course grade may be better handled by individuals or dyads casually formed among friends or “nearest neighbor(s),” while multiple person teams may be more appropriate for the completion of large-scale tasks with appreciable effect on the final course grade.

The observation that attitudes of graduate engineering students toward participation in active learning activities tend to vary little by degree program and major is helpful in a course drawing students from several departments. Therefore, the use of multiple strategies dependent on a match of task type and group formation methods will most likely engage the greater number of students. Additionally, identifying and acknowledging the impact drivers from other contexts – most notably, program milestone events such as qualifiers and thesis defenses – may have on student attitudes may help in designing strategies which will meet minimum resistance. Future work will include validation of these conclusions.

ACKNOWLEDGMENT
We thank the students from our classes in the Spring 2007 – Spring 2009 semesters their contributions to this research, and the FIE reviewers for their comments and suggestions. Susan was a postdoctoral fellow with the Center for the Advancement of Scholarship on Engineering Education, National Academy of Engineering, during this research.

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ATTITUDES WITH RESPECT TO GROUP WORK IN GENERAL

Attitudes with respect to group work in general are determined through responses to a set of six statements concerning preferences and plans with respect to group work participating in group learning activities among her master’s in statistics students in STAT 513/SYS 613 in the previous spring semester [1]. She later found out that these students were preparing for either their qualifiers or their comprehensive exams. Several of the students studying for their qualifiers had just joined the program that semester, and were competing for continuance and funding with students who had been in the program longer. The collective anxiety needed to be neutralized, and alternative pedagogies applied.

The students in the Spring 2009 cohort are also fulfilling a math requirement; however, we had ten non-first year students in the class. The stressors in the middle and final years of degree studies are different: research, thesis preparation and defense, and job hunting, for example.

III. Undergraduate Experience and Reasons for (Dis)liking Group Work

The responses to survey questions regarding the level of experience with group work as an undergraduate and reasons for (dis)liking group work are summarized here. The results are reported by gender, because initial analysis indicated that major and degree program, and for the Spring 2009 cohort, ethnicity, did not have an effect on the results. We believe one reason for this outcome is the relative homogeneity in undergraduate education among the respondents; another may be that all the students are pursuing research-based degrees. It may be that students seeking a professional or non-thesis degree might have a different outlook.

With respect to undergraduate experience with working in groups, senior capstone design projects and other class projects predominate with male students and other class projects with female students. A team-based Capstone pedagogic model is a popular one at many schools, including U.Va. [25]. All students in the surveyed cohorts report participating in group projects at least once during undergraduate studies.

With respect to reasons for (dis)liking group work, the genders agree as to the most popular reasons for liking working in groups (the opportunity to work with people with different abilities, intelligence, and points of view; and the ability to brainstorm), but lose agreement with respect to reasons for not liking working in groups. However, most students did express concerns about group members not contributing equally to the work product yet receiving the same grade as those who contributed to team success. An emerging theme, then, is given the degree of agreement between the genders, reasons for (dis)liking group work may be more rooted in personality than demographic variables. Recall, however, the relatively small proportion of female students in the class in both the observed cohorts; conclusions of this sort must of necessity be preliminary.

IV. Attitudes With Respect to Group Work in General

Attitudes with respect to group work in general are determined through responses to a set of six statements concerning preferences and plans with respect to group work.
TABLE IV
APMA 643 ATTITUDES TOWARDS GROUP LEARNING ACTIVITIES MEAN AND MEDIAN SURVEY RESPONSES – SPRING 2008 AND 2009

<table>
<thead>
<tr>
<th>Statement</th>
<th>Female (n = 10)</th>
<th>Male (n = 17)</th>
<th>Female (n = 16)</th>
<th>Male (n = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I prefer working alone</td>
<td>3.15</td>
<td>3</td>
<td>3.04</td>
<td>3</td>
</tr>
<tr>
<td>I like working in teams</td>
<td>3.75</td>
<td>4</td>
<td>3.85</td>
<td>4</td>
</tr>
<tr>
<td>I studied with other students in the class</td>
<td>4.1</td>
<td>4</td>
<td>2.83</td>
<td>3</td>
</tr>
<tr>
<td>Working with other students helps everyone learn the material better</td>
<td>4.3</td>
<td>4</td>
<td>3.88</td>
<td>4</td>
</tr>
<tr>
<td>I think it’s worthwhile to work in groups on…</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-class exercises</td>
<td>4.11</td>
<td>4</td>
<td>3.91</td>
<td>4</td>
</tr>
<tr>
<td>Homework problems</td>
<td>4.45</td>
<td>4.75</td>
<td>3.58</td>
<td>4</td>
</tr>
</tbody>
</table>

REFERENCES


[23] APMA 643 Instructor Toolkit Main Page (accessed throughout the Spring 2008 semester), https://toolkit.itc.virginia.edu/cgi-local/tk/UVa, SEAS, 2008 Spring APMA643-

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