The Effectiveness of Calculus Workgroup on Student Performance in Calculus: A Mixed-Methods Approach

by

Brita B. Schneiders

B.S., University of Colorado, 2013

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirements for the degree of

Master of Science

Department of Applied Mathematics

2014

This thesis entitled:
The Effectiveness of Calculus Workgroup on Student Performance in Calculus: A Mixed-Methods Approach
written by Brita B. Schneiders
has been approved for the Department of Applied Mathematics

Anne Dougherty

Mary Nelson

Murray Cox

Harvey Segur

Date _____

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Schneiders, Brita B. (M.S., Applied Mathematics)

The Effectiveness of Calculus Workgroup on Student Performance in Calculus: A Mixed-Methods Approach

Thesis directed by Dr. Anne Dougherty

Workgroup is an optional pass/fail supplemental course to Calculus that emphasizes collaborative work in a small group setting. We conduct a mixed-methods study to evaluate the effectiveness of Calculus 1 Workgroup on student performance in Calculus 1 for Engineers. We analyze a dataset that contains 733 observations and 35 predictor variables. We use AnswerTree software by SPSS to create decision trees to assess the biggest predicting factors for Calculus 1 course-grades. We then compare Workgroup students and non-Workgroup students based on factors resulting from AnswerTree, including predicted grade point average (PGPA), to evaluate the effectiveness of Workgroup on student performance. We find that in the academic year of 2013 - 2014, Workgroup did not significantly improve performance in Calculus.

We also analyze a survey taken by Workgroup students to have a better understanding of student attitudes toward Calculus, Workgroup, and Oral Assessments, a large component of Workgroup. Within the subgroup of Workgroup students, we compare students who are required to enroll in Workgroup to those who choose to enroll. We show that students who enroll in Workgroup have a higher PGPA on average than those who do not enroll. Further, we show that students who are required to take Workgroup (by scholarship) have a significantly higher PGPA than students who choose to enroll in Workgroup. Yet, we find no significant difference in course grade between required Workgroup students, non-required Workgroup students, and non-Workgroup students. Lastly, we note a correlation between the requirement to take Workgroup and attitude toward Workgroup.

Dedication

I dedicate this thesis to my students- past, present and future. May this and future education research better their experience with calculus and value of mathematics.

Acknowledgements

I am extremely grateful to a multitude of people for helping me complete this thesis. I first thank my two co-advisors and the rest of my superb and invested committee. I thank Mary Nelson, whose research is in Math Education, for her keen insight on what questions to ask and how to interpret my data. Thanks also to Anne Dougherty for her incredible support through this whole journey, through meeting frequently to check my progress and make sure I was on track. I greatly appreciated both of these two advisors' concern for present and future students, and how we might use our findings to improve students' calculus experience. I thank Murray Cox for his fresh perspective and enthusiastic ideas and thoughts. Thank you also to Harvey Segur who gave me great advice in several key moments, helping me maintain a sense of the bigger picture. All four of these committee members were outstanding mentors throughout this endeavor.

I also thank Dr. Daniel Knight for his constant willingness to help me with the statistics involved in this study. I would not have gotten far without his help. I thank my parents for their support and encouragement. Lastly, having taught two Workgroups per semester in the 2013 - 2014 academic year, I thank my Workgroup students for solidifying my intrinsic motivation to pursue this study. These wonderful students left a mark on me early in my teaching career; I will never forget what I learned in the classroom here at CU.

Contents

Chapter

1 Introduction 1

1.1 Review of Literature . . . 2

1.1.1 Workgroup Models . . . 2

1.1.2 Oral Assessments . . . 3

1.1.3 Past Research at the University of Colorado . . . 6

1.1.4 Student Attitudes and Performance . . . 7

1.1.5 Timeline: Workgroup and Orals at the University of Colorado . . . 7

1.2 Research Questions . . . 9

2 The Effect of Workgroup Enrollment on Calculus 1 Course-Grade 10

2.1 Methodology . . . 10

2.1.1 Description of Population . . . 11

2.1.2 AnswerTree by SPSS . . . 14

2.1.3 Further data analysis . . . 14

2.2 Results and Discussion . . . 15

2.3 Section Summary . . . 26

3 The Roles of Attitudes, Orals, and Instructors in Calculus Workgroup 30

3.1 Methodology . . . 30

3.1.1 Focus Groups . . . 30

3.1.2 Surveys 31
3.1.3 Learning Assistant and Teaching Assistant Surveys 32
3.1.4 Survey Analysis 32
3.2 Results and Discussion 33
3.2.1 Calculus 2 Survey Responses 33
3.2.2 Comparing Calculus 1, 2 and 3 Workgroups 38
3.3 Survey Summary 41

4 Conclusions 42
4.1 Future Directions 43

Bibliography 45

Appendix

A Fall 2013 Calculus 1 Students: Dataset Variables 47

B AnswerTree and the CHAID Algorithm 49

C Student Survey 50

D Learning Assistant Survey 54

E Teaching Assistant Survey 56

F Learning Assistant and Teaching Assistant Survey Analysis 57

Tables

Table

2.1 Descriptive Statistics for several independent variables 13

2.2 T-tests of biggest predicting factors and course-grades 24

2.3 T-tests of Stratified Random Sample 24

2.4 ANOVA mean PGPA by requirement results 25

2.5 Required Post-hoc Tukey HSD 25

2.6 Correlation Matrix of ALEKS Score, ALEKS Score, and Calculus 1 course-grade Workgroup 27

3.1 Survey T-Test, Questions 15, 17, 18, 19 35

3.2 Correlation Matrix: Q1, Q15, Q19, PGPA, Calculus 1 and 2 grades 37

3.3 T-test of Stratified Random Sample: Required versus Non-required 38

F.1 LA significant survey questions 57

Figures

Figure

2.1 PGPA ranges for all students, men and women 12

2.2 Calculus 1 student body by gender and workgroup enrollment 12

2.3 Workgroup enrollment and gender 12

2.4 AnswerTree 1.1: Predicting factors of Calculus 1 course-grade (all grades) 18

2.5 AnswerTree 1.2: Predicting factors of Calculus 1 course-grade (ternary) 19

2.6 AnswerTree 1.3: Predicting factors of Calculus 1 course-grade (binary) 20

2.7 AnswerTree: Enrollment in Workgroup 22

2.8 Scatterplot of AST score versus ALEKS score 28

3.1 Calculus 2 Survey Averages, divided by Requirement 34

3.2 Calculus 2 compared with Calculus 3 Workgroup 39

Chapter 1

Introduction

Calculus Workgroup (GEEN 1350) is a one-credit course offered at the University of Colorado at Boulder in the College of Engineering and Applied Sciences. Required for some students and optional for others, the course is supplemental to the Calculus for Engineers sequence of Applied Math courses. Workgroup is intended to provide extra support for students in calculus by reinforcing concepts through group work and oral assessments.

The present study focuses on one cross-section of Calculus 1 students, comparing students who enrolled in Calculus 1 Workgroup with those who did not. We hypothesize that Workgroup makes a significant difference for students who are recommended to take it, based on high-school calculus credits, pre-assessment test scores, and other factors. This study also examines student attitude toward Workgroup and Orals, supported by survey results.

Oral Assessments Orals are facilitated by one person, either a Teaching Assistant, Learning Assistant, or Instructor. Students use a whiteboard or chalkboard to answer questions, which are primarily conceptual in nature. Students try to answer the question on their own, and then may collaborate with classmates. Orals are facilitated in two settings: one is called Oral Review Sessions, which take place before midterms and involve about five students each. These are one hour long and completely voluntary. The students are not graded on their performance. The other setting is in Calculus Workgroup, where students pass or fail based solely on attendance and participation.

Calculus Workgroups Workgroup is a one-credit supplemental course to Calculus lec-

ture. It is required for some students with certain scholarships, and otherwise it is optional. The structure of the course is the following: students come to Workgroup once a week for an hour and forty minutes and work in groups of 5 or 6 students. About two thirds of the time is spent on worksheets of challenging problems related to current lecture material, and one third is spent on Orals with the Teaching Assistant or a Learning Assistant. Students are graded on attendance and participation. The idea is to create a stress-free environment where students feel comfortable asking questions, can realize that other students have the same misconceptions as they do, and realize that calculus is challenging but accessible to them.

1.1 Review of Literature

1.1.1 Workgroup Models

Our workgroups are based on the Emerging Scholars Program (ESP), called the Professional Development Program Mathematics Workshop (PDP Workshop), which was started by Uri Treisman at the University of California at Berkeley in 1974 [23]. This program was designed in response to ethnographic research at UC Berkeley that showed a contrast in study habits between Chinese students and black students. While Chinese students tended to study in groups and perform very well, black students worked in isolation and were struggling in Calculus [8]. The very same study habits that helped minority students be successful in high-school (studying separately from less motivated students) were hurting their success in Introductory Calculus.

The ESP model therefore targeted high-achieving minority students, with the aim of uniting them with other motivated, high-achieving students. An extensive recruitment and interview process led to a select group of students. The workshop met several times a week for two hours per session, unlike Workgroup at CU, which meets once per week for one hour and forty minutes. Due to the untraditional nature of these workshops, Treisman recommends a graduate student in math and science teaching to instruct these workshops, as opposed to graduate teaching assistants (GTAs). In Applied Mathematics, the chosen instructors of CU Workgroups are GTAs [23].

Calculus Workgroup at the University of Colorado at Boulder is modeled after the PDP Workshop, though with slightly altered goals. While the PDP Workshop is an honors program and is explicitly not meant to be a remedial study program, Workgroup at CU is meant for students who need the extra support, as deemed by their advisors. The course is required for students who are recipients of BOLD (Broadening Opportunity through Leadership and Diversity) and GoldShirt scholarships, both of which emphasize diversity. For a more thorough explanation of these programs, see Section 1.1.5. Beyond these scholarship students, Workgroup is optional for all other calculus students. Students who score below the optimum threshold on the calculus pre-assessment test (ALEKS), a 75%, at the beginning of the semester are urged to enroll in Workgroup, though they are not required to do so[1] . Explicitly, students are recruited for Workgroup by calculus needs, unlike the recruitment process for the ESP model. However, due to the current (2013 - 2014) requirement of BOLD and GoldShirt students to enroll Workgroup, ethnicity is currently a large implicit component of Workgroup enrollment.

The main purpose of each Workgroup session at CU is very similar for the ESP model workshop. Both meet to reinforce concepts and skills by doing additional work, including extensions of homework problems that introduce more advanced topics [23]. However, there is no homework required of workgroup students at CU. The course is completely supplemental to the calculus course and recitation: students are only expected to show up each week and actively participate during the one hour and forty minute session.

1.1.2 Oral Assessments

An emphasis on Oral Communication in mathematics is relatively new in modern US education. Mathematics *as a language*, especially in the context of education, was most notably brought up in 1987 in David Pimm's book, Speaking Mathematically. In this book, Pimm explains to educators how important it is to teach math as a language, citing examples like the difference

[1] We note that in the Fall of 2014, an ALEKS pre-assessment score of at least 76% is required for all students enrolling in Calculus 1

between a student's and a teacher's understanding of words like "any" and "some" in the context of mathematics. Pimm also touches on something that sounds very similar to what are known as "Oral Assessments" at CU: "Yet it is also the reported experience of many teachers that merely as a result of asking pupils to try to articulate what the difficulty is that they are experiencing, halfway through the resulting explanation pupils often say something like: 'Oh I see now, thank you very much for helping me.' It seems that the act of attempting to express their thoughts aloud in words has helped pupils to clarify and organize the thoughts themselves" [19, p. 23].

Around the same time that Pimm wrote his book, K12 education started to address math as a language. *The Curriculum and Evaluation Standards for School Mathematics* (NCTM) starting shifting in the late 1980's and early 1990s to "learning to communicate mathematically", stating one of the new math standards to be, "The development of a student's power to use mathematics involves learning the signs, symbols and terms of mathematics. This is best accomplished in problem situations in which students have an opportunity to read, write, and discuss ideas in which the use of the language of mathematics becomes natural" [6]. Educators have started to emphasize the necessity for students to talk through mathematical processes. This is the fundamental goal of Orals at CU: to help students use speech to clarify concepts.

At CU, this is a more formal process where students speak aloud in groups, and write on whiteboards. Orals effectively aim to do what Rose Asera describes as one of the PDP Workshop accomplishments: "for those students who were accustomed to working alone, the group provided the model for how to approach a calculus problem from different points of view", and further, "over time, students became skilled at, and internalized, this conversation - this process of incorporating various perspectives into solving a problem" [2]. This conversation is now thought to be critical to mathematical understanding. Dr. Mary Nelson found that students value Orals for other reasons as well. Some comment that Orals help them see how others approach a problem, others comment that Orals help clarify which concepts one understands versus which should be studied more before a test, and still others report that they like the individual attention, which helps clear up misunderstandings [14].

Nelson found Oral Assessments to be very successful in a study during the 2003 - 2004 academic year [15, 16]. Her treatment group was all students in a year-long calculus course, a total of 36 students. 62% of these students were considered "at-risk" because of their poor pre-assessment test scores. In contrast, only 16% of the control group, the regular semester-long calculus course in Fall 2003, were considered at-risk. The major treatment of her group was Oral Assessments, which were offered before each exam and were completely voluntary for the treatment group. She found that at-risk students in the treatment group performed significantly better than control at-risk students, both in course-grade and their grade on the final exam (which was the same for both groups). At-risk treatment students performed better than even workgroup students (which did not involve Orals at the time), which means that time-on-task could not explain the significant differences. Nelson says other factors may have been at play, but that none of them explained such dramatic results.

Several undergraduate mathematics programs have implemented oral communication into their curriculum in recent years. Two schools in the United Kingdom, The University of Durham and The University of East Anglia, recently introduced an oral performance assessment into their curriculum. In their case, "oral performance assessment" means "an assessment where the student is working on a problem with a tutor, while able to both write and converse about their attempts at a solution and the mathematics underpinning it" [9]. This seems to be a step forward in the university setting.

However, there are two main criticisms of this assessment: fairness and anxiety [9]. It is debatable whether anxiety arises from the novelty of an oral assessment, or from something inherent in the orality of the assessment. However, little research has been done on comparing anxiety caused by different forms of assessment. Further, Oral Assessments at CU are not graded, as they are in the above schools in the UK, which we believe reduces anxiety. This will be addressed in a survey administered to students, addressed in Chapter 3.

The concern for fairness arises from the fact that Oral Assessments cannot be anonymized, but this is hardly an issue at CU since, again, Oral Assessments are not graded. Orals are completely

voluntary, and are described as "one building block of a safe, accepting community for students" [16, p. 49]. Therefore, the two major concerns addressed in Iannone and Simpson's study are minor issues, if relevant at all.

1.1.3 Past Research at the University of Colorado

Several studies have been done on predicting student performance in calculus at CU. In 1998, Karplus found the best predicting factor to be the locally developed pre-assessment test, called AST [11]. In 2000, however, McColl and Dougherty found high-school calculus experience to be the biggest predicting factor, with the AST coming second. They did, however, find that the pre-assessment test was the biggest predicting factor for performance in Calculus 2, even more so than performance in Calculus 1 [13].

In 2003, Daniel Cooley looked at the effectiveness of Calculus 1 Workgroup on Calculus 1 course-grade in addition to predicting factors of performance in Calculus 1. He found the biggest predicting factor of performance in calculus was whether the student had calculus experience in high-school. Second to this was the student's high-school grade-point average. For his analysis on Calculus 1 Workgroup, he separated the students into four subgroups based on their AST scores. He then compared the average course-grade for each subgroup using an ANOVA test with a post-hoc Tukey HSD. He found that not all workgroup students showed a significant improvement in their Calculus 1 grades, but that students in the middle-low range of AST score did [5]. This is the group of students for whom workgroup is intended.

In addition to the AST, the present study looks at ALEKS test, which was recently adopted to place students in their first math course at CU. This allows us to compare the predictive ability of both assessments tests. The independent variables used are much the same as those used in the studies of Karplus, McColl and Cooley, including high-school grade-point average, ACT and SAT scores, high-school calculus experience, etc. The present study uses several other factors, including Advanced Placement credit hours and predicted grade-point average (calculated form high-school GPA and either ACT or SAT math score) . The methodology for this study was heavily influenced

by the findings of the above three studies.

1.1.4 Student Attitudes and Performance

Given that some students are required to take Calculus Workgroup, this study also addresses the relationship between attitude and student performance in calculus. Many studies have found a significant correlation between attitude and course performance. Pyzdrowski et. al. found attitude to have a stronger correlation to course performance than high-school grade-point average or their locally developed assessment test, Calculus Readiness Assessment [20]. Mary Worthley, who focused on the failure/drop rate of freshman STEM students in Calculus at Colorado State University for her PhD dissertation, found one of the biggest predicting factors of performance in calculus to be motivation and student strategy constructs, measured by the Motivated Strategies for Learning Questionnaire (MSLQ) instrument [25]. Further, House (1995) found three attitude-related indicators to be strongly correlated with calculus performance: self-ratings of overall academic ability, self-ratings of mathematical ability, and expectation of graduating with honors [7].

The self-ratings House used are similar to questions workgroup students were asked in this study. Students were asked questions about their perception of whether they will receive a better grade for having taken workgroup, and whether they feel they score better on tests due to workgroup. Students were not asked, however, to self-rate their overall academic ability, math ability, or expectation of graduating with honors, nor did they self-report time spent on calculus. The present survey focused on the more immediate future.

1.1.5 Timeline: Workgroup and Orals at the University of Colorado

Calculus 1 Workgroup first started at the University of Colorado Boulder in the Fall of 1994. It was heavily motivated by the Treisman model, though it was aimed at B or C range students, not at A range students. It started with only three sections, but has increased to seven sections offered every fall and three in the spring. Since the inception of Workgroup, it has expanded to other levels of calculus. Calculus 2 Workgroup began in the Spring of 1998, while Calculus 3 Workgroup

started in the Fall of 2011.

Nelson, a co-advisor of this thesis, wrote her dissertation at CU on a reform approach to calculus instruction, and its impact on student retention, grades and understanding. This approach included oral assessments, something Dr. Nelson had experimented with in a college liberal arts mathematics course when a particular class was struggling with the material. Nelson found that even her weakest students with respect to mathematics could understand the most difficult material when they discussed it out loud [15].

Nelson initiated Oral Assessments at the University of Colorado as test review for Calculus courses in 2007 [16]. A year after Oral Assessments were implemented in the CU Applied Math department, Nelson compared the DFW (Drop, Fail, Withdraw) rates before and after the implementation of Orals. The nine year average DFW rates for Fall Calculus 1 and Spring Calculus 2 were 33% and 26%, respectively. The 2007 - 2008 rates were 21% and 17% respectively, after the addition of oral reviews [16]. These reduced rates were consistent for the subsequent five years of her study.

Since 2008, the use of Oral Assessments have expanded to other Applied Math courses, including Complex Variables, and Fourier Series and Boundary Value Problems, depending on the instructor in a given semester. Oral Assessments have also expanded to other CU departments like Mechanical Engineering and Aerospace Engineering, and several other schools, including Seattle University, Penn State University, University of Santa Clara, Shippensberg University, George Mason University, and some Boulder high-schools [16]. Due to the success of Oral Assessments, they were also added to Calculus Workgroups in 2011, and are now a critical component of workgroups, making up about a third of each student's time in Workgroup each week.

The last critical piece of background for this study is when Workgroup became required for certain students. The BOLD program includes a scholarship component that emphasizes building an engineering work force that is diverse in gender, ethnicity and socioeconomic status, and whose vision is to "graduate outstanding engineers at numbers that mirror Colorado's diverse population" [1]. BOLD therefore recruits many minority and first generation college students who are strong

academically. BOLD also hosts the GoldShirt Program, a five year program for promising, talented students who need one more year of preparation before beginning the full undergraduate engineering curriculum. These students are not accepted into the College of Engineering and Applied Sciences initially, most likely due to poor preparation and resources, but show strong academic potential. As this program is through BOLD, it also has a focus on diversity. Due to the success of Orals and Workgroup, the BOLD program started requiring its BOLD and GoldShirt scholarship recipients to enroll in Workgroup in Fall of 2011. Whether a student is required to enroll in Workgroup is a large component of the survey analysis in this study.

1.2 Research Questions

How does the population of Calculus 1 Workgroup students compare to that of non-Workgroup students? Workgroup is intended for students who will need the extra support to succeed in Calculus (a grade of C- or higher, according to the College of Engineering requirements, or B- or higher for certain scholarship students). This includes students who scored poorly on the ALEKS pre-assessment test, have little to no calculus experience, have a low high-school GPA, and a variety of other factors. Does the population of workgroup students match these factors?

What is the impact of Calculus 1 Workgroup on course-grade in Calculus 1 for Engineers? We hypothesize that students who take workgroup significantly improve their course-grades, due to enrolling in Workgroup. Is this the case?

What is the role of Oral Assessments in Workgroup? We set forth to discover students' attitudes toward Oral Assessments. Do they find them helpful? Do they see them merely as a break from their Workgroup worksheet? Are Oral Assessments considered a valuable part of Workgroup?

Using a quantitative dataset from Fall 2013 and student survey answers from Spring 2014, we seek to answer the above questions.

Chapter 2

The Effect of Workgroup Enrollment on Calculus 1 Course-Grade

2.1 Methodology

Past research at the University of Colorado, within the context of Calculus for Engineers, focused on the best way to determine predicting factors for student performance in Calculus. These factors included quantitative measures such as High-School GPA, ACT and SAT scores, as well as qualitative factors such as gender, race, ethnicity, residency, parents' highest level of education, and others. Furthermore, these factors included Year in University (freshman, sophomore, etc.), whether the student is a transfer student, and if so, what that student's transfer GPA was. Anna Karplus first looked at different predictive models for performance in calculus, concluding that Exhaustive Chi-Squared Automatic Interaction Detection (CHAID) predicted better than models where students were grouped by prearranged cutoffs of one criterion and further split by more criteria (called "gray models") [11]. McColl and Dougherty also analyzed the accuracy of multiple predictive methods, this time comparing Exhaustive CHAID with CHAID and regression models. Consistent with Karplus's findings, McColl and Dougherty also determined that Exhaustive CHAID rendered the best results for predicting student performance in Calculus [13]. Unlike CHAID, *Exhaustive* CHAID does not bias against variables with a large quantity of categories. Since we are dealing with variables like letter grade (totaling 15 categories in Figure 2.4), this lack of bias makes Exhaustive CHAID ideal for the present study. See Appendix B for further details on CHAID algorithms and Answer Tree analysis.

To conduct this study, we requested specific data for all students who enrolled in Calculus

1 for Engineers (APPM 1350) in the Fall of 2013. For each student enrolled, I obtained data for the most predictive factors determined in these previous studies, as well as a few more possibly relevant factors. In addition to these factors, I include AP hours, AST score and ALEKS score (a pre-assessment test given to all incoming Calculus students), and several other factors. For a complete list, please see Appendix A.

2.1.1 Description of Population

Focus groups held in the Spring of 2013 (discussed in Chapter 3: Qualitative Analysis) revealed not all Workgroup teaching assistants were facilitating Oral Assessments within their workgroups in the academic year of 2012 - 2013. Therefore, I used only data from Fall 2013 to ensure consistency in Orals Facilitation. I was a Workgroup teaching assistant during that same semester, and can say very confidently that all Calculus 1 Workgroup teaching assistants (a total of 5) were facilitating Orals as I was. We also each received identical instruction on how to facilitate Orals from Dr. Mary Nelson at the beginning of the semester.

In light of the above, the dataset for this analysis consists of all students who were enrolled in APPM 1350 in the Fall of 2013, which totaled 733 students. This dataset contains 41 variables for each student: 6 dependent factors (course-grades and cumulative GPA) and 35 independent factors, ranging from quantitative aspects such as Predicted Grade-Point Average (PGPA, calculated from HS GPA and ACT or SAT math score), HS GPA, ACT score, SAT score, as well as qualitative factors such as Ethnicity, Race, Gender, Parents' highest level of Education, and Calculus 1 Workgroup enrollment. Again, the full list can be found in Appendix A.

Characteristics of this population that are later determined to be significantly different between Workgroup student and non-Workgroup student populations (PGPA, Gender) are shown visually in Figures 2.1, 2.2 and 2.3. Several nontrivial numeric factors are summarized in Table 2.1.

In Figure 2.1, we see that though there is a wide range of PGPAs for incoming Calculus 1 students, the majority lies on the right side, in the 3.3 - 3.6 PGPA range. Notice that the trends for all students and male students (blue and red, respectively) look very similar to each other due

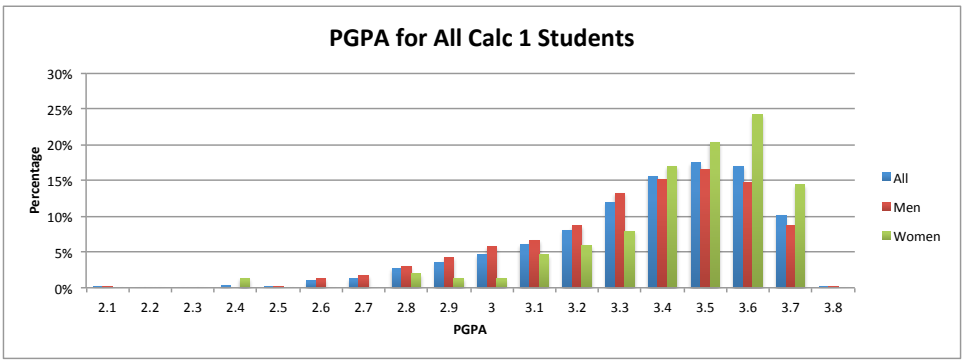

Figure 2.1: Here is a graph of student PGPAs for All students, Men, and Women.

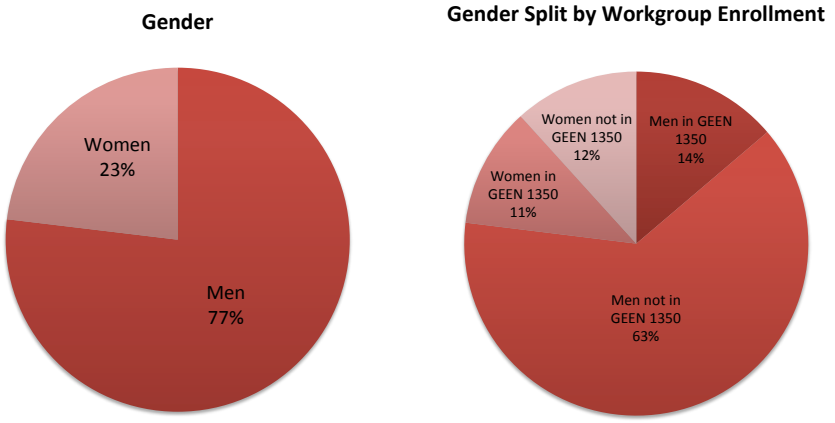

Figure 2.2: Gender breakdown for Calculus 1 Students in Fall 2013. The data are first shown overall, and then are split by enrollment in Calculus 1 Workgroup.

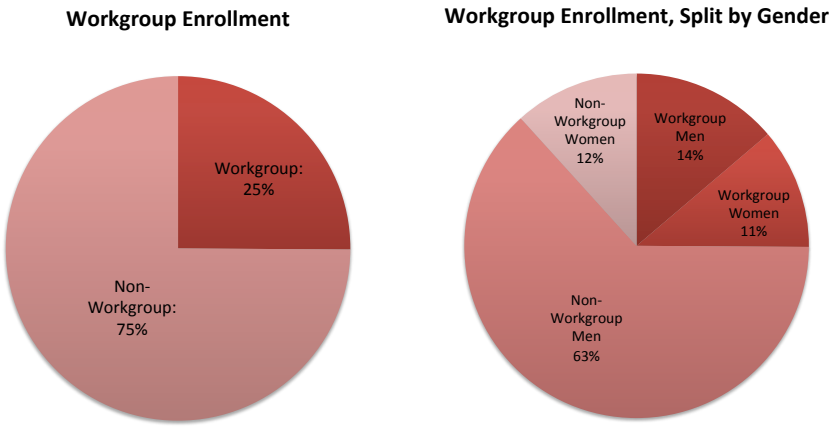

Figure 2.3: Workgroup Enrollment Breakdown for Fall 2013. It is first shown overall, and then is split by gender.

	N	Minimum	Maximum	Mean	Std. Deviation
HS_GPA	664	.60	4.00	3.7823	.32616
ACT_C	569	17.0	36.0	29.019	3.5007
ACT_M	569	16.0	36.0	29.786	3.4118
HS_Calc	660	0.00	4.20	1.0709	.67106
AP_Hrs	488	0.0	57.0	11.574	11.2084
PGPA	624	2.04	3.71	3.3138	.26702
ALEKS_Score	649	9.0	98.0	81.835	11.5580
AST_Score	684	0.0	30.0	23.984	4.0554

Table 2.1: The following table shows the minimum, maximum, mean and standard deviation of the main numeric factors of this dataset.

to a majority of male students, while female students (in green) lie slightly to the right. We will see in Table 2.2 that women come in with a higher mean PGPA than males do, but since women make up only 23% of Calculus 1 students (Figure 2.2), this difference does not alter the trend of all students substantially.

We see from Figure 2.2 that about half of female Calculus 1 students enroll in workgroup (49% of women). This amounts to 83 women who enrolled in GEEN 1350 in Fall 2013. Though only 18% of men enrolled in GEEN 1350, they still outnumbered the number of female workgroup students with 101 male workgroup students. Therefore, women made up about 45% of workgroup students.

Table 2.1 gives the mean, maximum and minimum values for several quantitative factors. We can see that there is a wide range of ability in this group of students: ACT scores range from 16 to 36, Advanced Placement credit hours (AP_Hrs) range from 0 to 57 (which amounts to over 10 AP courses), and the ALEKS Score ranges from 9 to 98. Means of measurement variables (High-School GPA, ACT, PGPA, ALEKS Score and AST Score) tend to lie closer to the maximum than the minimum, however (as shown visually in Figure 2.1 of PGPAs).

2.1.2 AnswerTree by SPSS

Since the past studies at CU are 10 - 15 years old, the most impactful factors may have changed over time. My first step was therefore to run AnswerTree with the Exhaustive CHAID method in the statistical program SPSS to determine predicting factors. It should be noted that AnswerTree is an explorative test only, and therefore should not be used as a conclusive test. For this reason, I use the results of AnswerTree only to narrow down my list of 36 independent variables to just the most critical few, thus informing which factors to use in future tests of this study. The independent variables used are all listed in Appendix A except for course-grades (variables 26 - 28 and 30 - 32), including the factors listed in Table 2.1. The dependent variable is course-grade in APPM 1350. This AnswerTree analysis confirms and clarifies which are the best predicting factors for performance in calculus for my particular dataset. This AnswerTree is run in each of three cases: 1) course-grade is 15 variables (A, A-, B+, ...), 2) course-grade is 3 variables (A to B-, C+ to C-, and D+ to W), and 3) course-grade is 2 variables (A to C-, D+ to W).

I run a second AnswerTree to determine the predicting factors for enrollment in GEEN 1350. All of the same independent variables from AnswerTree 1 are used (except for GEEN 1350 enrollment, which was treated as the dependent variable) in the second analysis.

2.1.3 Further data analysis

The main predicting factors for performance in APPM 1350 are determined to be AST score, high-school GPA and AP hours, while the biggest predicting factors for Workgroup enrollment were Gender and AP credit hours. Note, however, that we use PGPA (which is heavily dependent on high-school GPA) in lieu of high-school GPA. I compare workgroup and non-workgroup students based on these factors, and also compare their performance in APPM 1350. Further, I break down GEEN 1350 students into those who were required to enroll versus those who chose to enroll. Using data from the survey analyzed in Chapter 3, I do an ANOVA test with Tukey HSD Post-Hoc analysis on mean PGPA for three groups: those required to enroll in GEEN 1360, those enrolled in

GEEN 1360 but not required, and those not required nor enrolled in GEEN 1360. Note that since the survey was taken in Spring of 2014, I only include students from the Fall 2013 dataset who also enrolled in Calculus 2 for Engineers (APPM 1360) in the spring semester.

Even though AST score is the biggest predicting factor for student performance in Calculus, we find no difference in AST score between Workgroup and non-Workgroup students. We do, however, find PGPA to be the only characteristic that is significantly different between Workgroup and non-Workgroup populations (we see this in Table 2.1). Therefore, I take a stratified random sample of APPM 1350 students, stratified by PGPA. Doing so removes the PGPA bias and gives a clearer comparison of performance in APPM 1350. As the biggest predictor for Workgroup Enrollment is gender (Figure 2.7), the sample is also stratified by gender. The sample included the same number of male and female GEEN 1350 students as it did non-Workgroup students, with identical mean PGPAs. This included 55 women and 80 men in GEEN 1350, and 55 women and 80 men who were not enrolled in GEEN 1350.

2.2 Results and Discussion

Figures 2.4, 2.5 and Figure 2.6 look at the best predicting factors of calculus performance, though they address slightly different questions. Figure 2.4 asks what the predicting factors of course grade are, where AnswerTree distinguishes between sub-grades (i.e. B+, B, B- are distinct grades). Figure 2.5 splits the grades into three groups: (1) A to B-, (2) C+ to C-, and (3) D, F, W. A course-grade of B- or higher is required for scholarship students to move on to Calculus 2. Further, students with a C or C- in Calculus 1 are predicted to do poorly in Calculus 2. Historically, about 50% of students who earn a C or C- in Calculus 1 and continue on to Calculus 2 earn a D, F or W in Calculus 2. Therefore, Figure 2.5 asks how to predict students who will do well in Calculus 1 and 2, versus students who will pass in Calculus 1 but struggle in Calculus 2, versus students who will drop, fail or withdraw from the course. Figure 2.6 splits the grades into two categories, passing (A to C-), and DFW (Drop, Fail, Withdraw). This is because students must earn a C- or higher in Calculus 1 to move on to Calculus 2 by the College of Engineering and Applied Sciences

standards.

We first note that Assessment_Score (AST score) is the best predicting factor for each of the three AnswerTrees. This is consistent with the findings of Karplus [11]. Figure 2.4 splits AST score into three intervals, with the lowest cutoff being 21, while Figures 2.5 and 2.6 split the AST score into five intervals, with the lowest cutoff being 18. The AST score cutoff of 18 is consistent with past research at CU: students who score an 18 or lower on the AST are predicted to drop, fail or withdraw from Calculus 1.

Looking at Figure 2.4, we see that the second best predictors are ALEKS_Numbers (ALEKS score on the Numbers section) and HS_GPA (high school grade-point average). ALEKS_Numbers is the next best predictor for students who scored 21 or less on the AST or have a missing score. Within this subset of students, 65% of those who score a 94 or less on ALEKS_Numbers (or have a missing score) withdraw or fail, while only 32.4% of those who score higher than a 94 fail or withdraw. Shifting to the (21, 26] interval of AST scores, we see that high-school GPA is the next best predictor. The biggest percentage of students with a high-school GPA less than or equal to 3.71 earn a B, at 23.5%. The next subset of students, those with a high-school GPA between 3.71 and 3.94, earn a C at 29.5% while only 15.5% of students earn a B. 30.5% of students with a high-school GPA greater than 3.94 earn a B. We would expect the middle interval of high-school GPA students to earn higher grades in Calculus 1 than the lower interval. However, we see that these subgroups of students merely have a different spread of grades. This suggests that perhaps the second and third AnswerTrees offer more telling information. The last subset of students, those with an AST score greater than 26, are also next predicted by high-school GPA. 91.4% of students with an AST score greater than 26 and a high-school GPA greater than 3.94 earn a B- or better, while 59.3% of students with an AST score greater than 26 but a high-school GPA of 3.94 or less earn a B- or higher in Calculus 1.

In Figure 2.5, We see from Node 1 that 54.3% of students earn a B- or higher (Group 1) in Calculus 1, 22.8% earn a C-, C or C+ (Group 2), and the remaining 22.9% drop, fail or withdraw from the course (Group 3). The best predicting factor is AST score, once again. There is a clear

increase in percentage of students who earn a B- or higher in Calculus 1 as AST score increases. Only 14.1% of students who score an 18 or lower on the AST earn a B- or higher, while 87.6% of students who score higher than a 27 on the AST earn a B- or higher. Similarly, there is a clear negative relationship between percentage of students who drop, fail or withdraw from Calculus 1 (Group 3) as AST score increases. 65.6% of students who score an 18 or lower on the AST drop, fail or withdraw from the course while only 2.5% of those who score higher than a 27 on the AST get a D, F or W. This AnswerTree seems to tell us a bit more information than the first AnswerTree, since we are interested in knowing whether a student will pass and how they will do in Calculus 2, rather than the difference between an A and an A-. In this AnswerTree, the second best predictors are ALEKS_Polynomials (the ALEKS score on the Polynomials section) and high-school GPA, and the third best predictor is Advanced Placement hours (AP_hrs).

Figure 2.6 is simplified further. We see again that the best predicting factor is AST score, where the scores are split into the same intervals found in Figure 2.5. We see a clear positive relationship between AST score and students who pass the course with a C- or higher (Group 1). 34.4% of students with an AST score less than or equal to 18, 50.7% of those with AST between 18 and 21 (or missing), 78.4% of those with AST between 21 and 23, 88.5% of those with AST between 23 and 27, and 97.5% of those with AST greater than 27 passed the course with a C- or higher.

Students in the (18, 21] interval of AST scores are further predicted by their ALEKS score on the Polynomials section. 60.7% of students who scored an 86 or lower (or had missing data) fail or withdraw from the course (Group 3), while 39.4% of students who scored higher than an 86 on the ALEKS Polynomials section withdraw or fail. The next interval with a second best predictor is the (23, 27] bracket of AST scores. Students in this interval are next predicted by high-school GPA. In looking at the first two of the three high-school GPA intervals, 3.71 and lower and (3.71, 3.94], we see that the same percentage of students earn a B- or higher (49.2%). However, 33.3% of students with high-school GPA less than or equal to 3.71 fail or withdraw, while only 7.7% of students in the (3.71, 3.94] range of high-school GPAs fail or withdraw. This means a bigger proportion of students

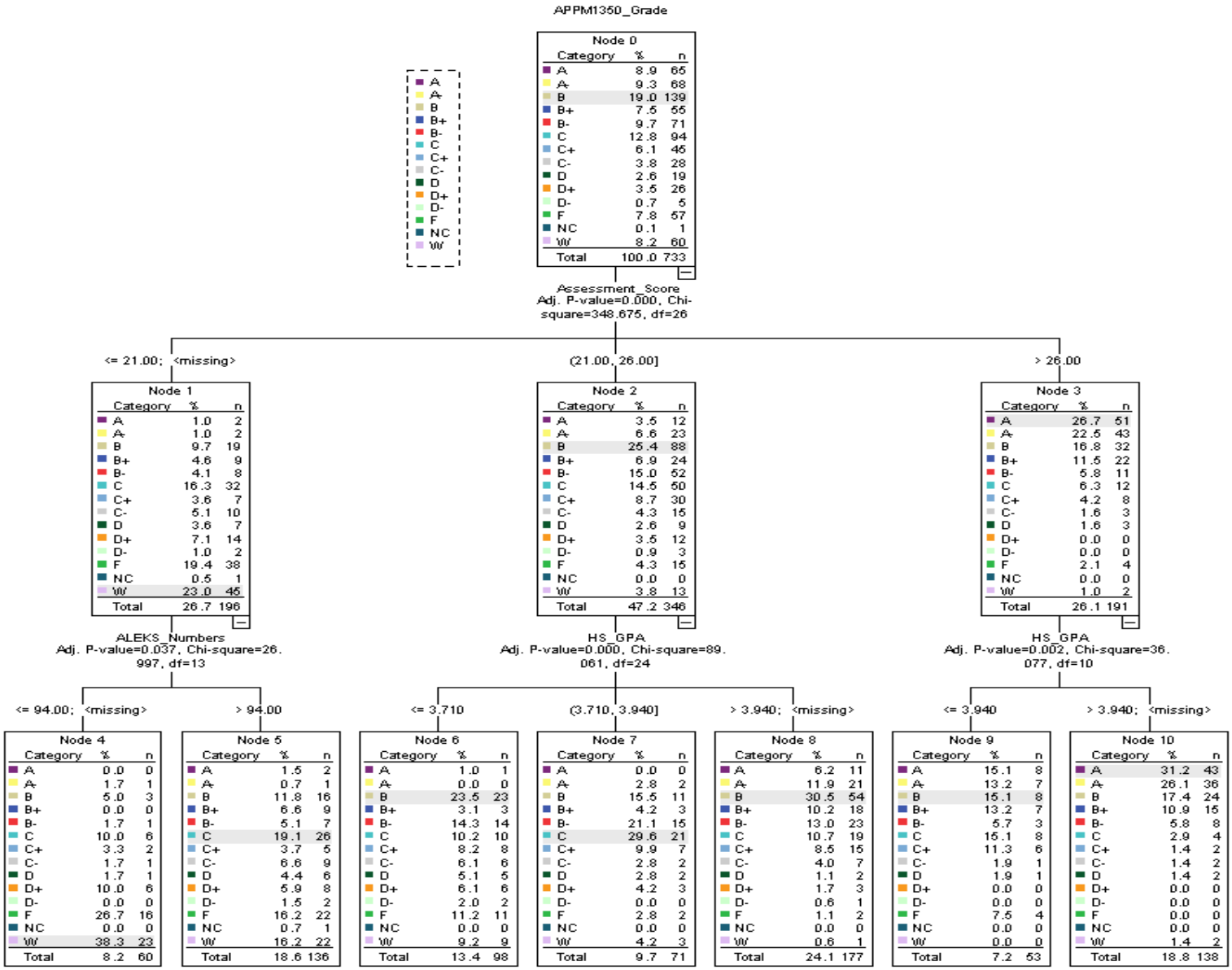

Figure 2.4: AnswerTree: Predicting factors for Performance in Calculus 1. Risk Factor was found to be .730. Recall that Risk Factor means the percentage of grades predicted incorrectly.

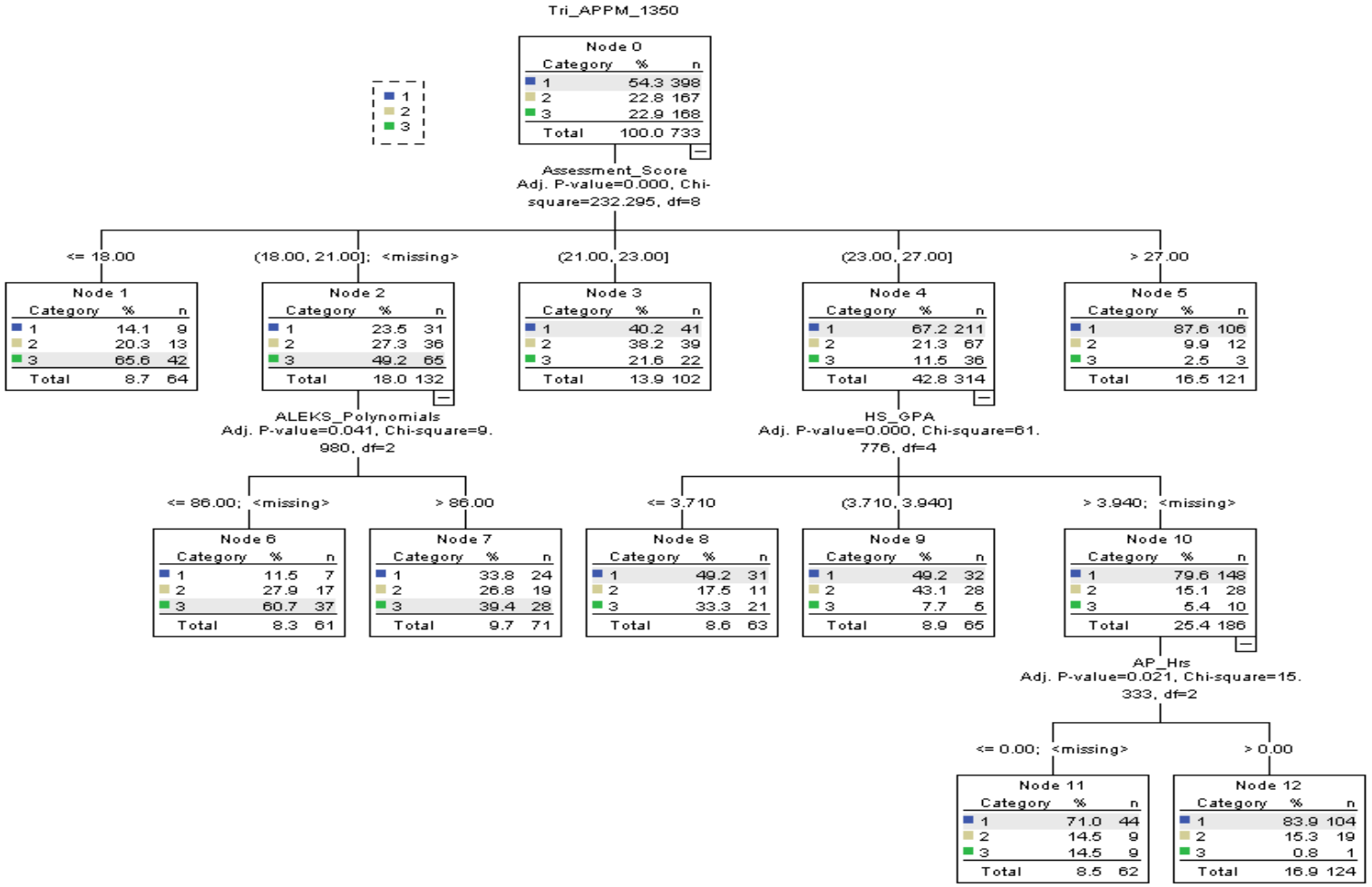

Figure 2.5: AnswerTree: Predicting factors for Performance in Calculus 1. Course-grade is split into three categories: (1) A to B-, (2) C+ to C-, (3) D+ to D-, F and W. Risk Factor was found to be .366, meaning 36.6% grades are predicted incorrectly.

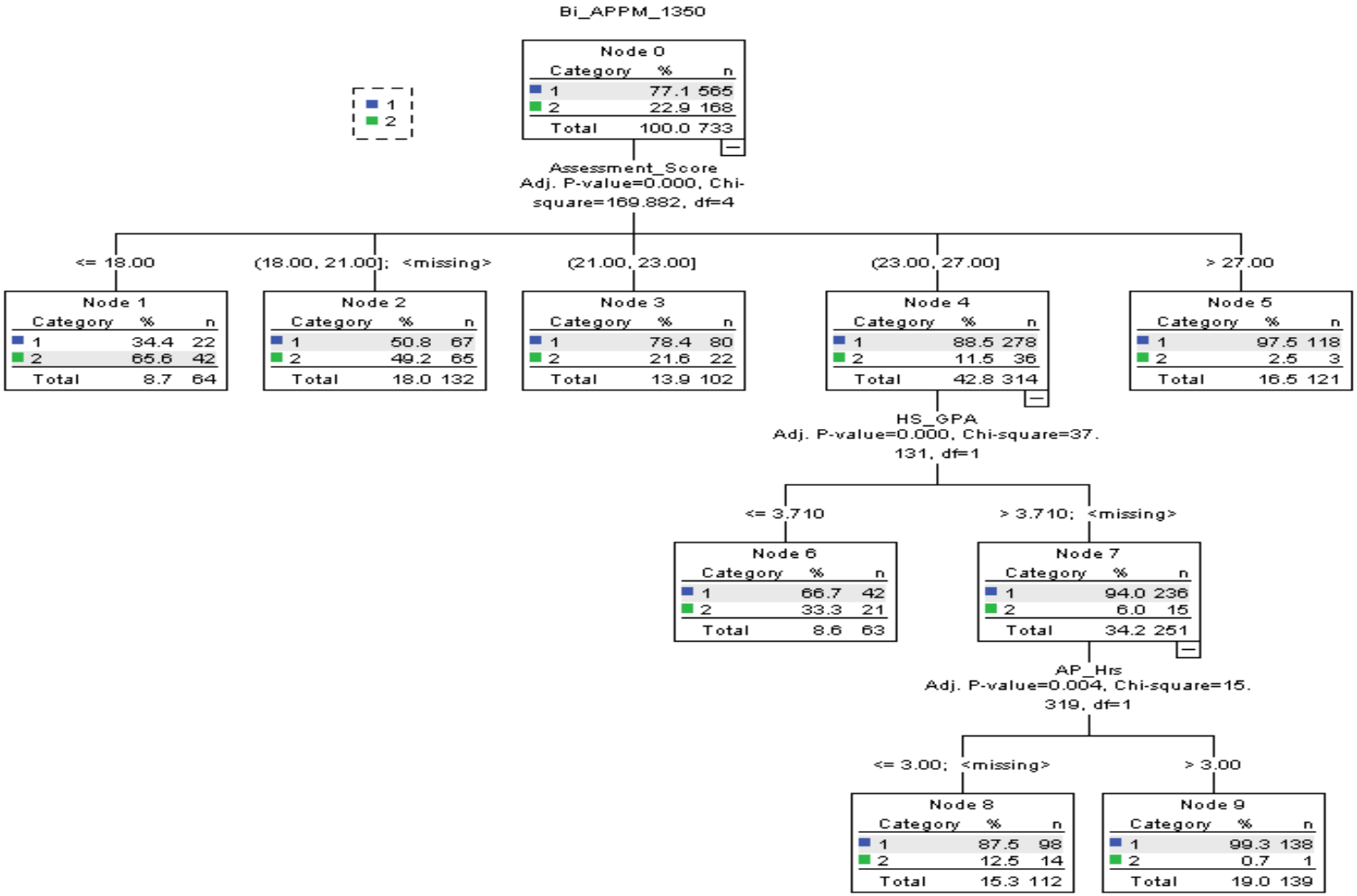

Figure 2.6: AnswerTree: Predicting factors for Performance in Calculus 1, where course-grade is split into two categories: (1) passing (by the standards of the College of Engineering and Applied Sciences: A to C-), and (2) the D,F,W rate (drop, fail, withdraw). Risk Factor was found to be .202, meaning 20.2% of grades are predicted incorrectly.

earn a C-, C or C+ in the second interval. Students with a high-school GPA greater than 3.94 (or missing data) have a higher proportion of students who earn a B- or higher (79.6%), and a lower proportion of students who fail or withdraw from the course (5.4%). Students with a high-school GPA greater than 3.94 are further predicted by the number of Advanced Placement hours they took in high school. 71.0% of students with no AP credit (or missing data) earn a B- or higher in Calculus 1, 14.5% earn a C-, C or C+, and the remaining 14.5% fail or withdraw (a D+ or lower). 83.9% of students who earn any AP credit (greater than 0 credit hours) earn a B- or higher, 15.3% earn a C-, C or C+, and only .8% fail or withdraw from the course. This suggests that having so much as one AP credit hour, meaning some exposure to a college level course is correlated with doing well in Calculus 1.

In comparing Figures 2.4, 2.6 and Figure 2.5, we see that the Risk Factor decreases as we decrease the number of categories. This makes sense, as there is less room for error with fewer categories.

AnswerTree 2: Figure 2.7 shows the predicting factors for enrollment in GEEN 1350. The biggest predicting factor is gender. Right away, before delving any deeper, we can see that Workgroup is not best predicted by any quantitative variable like PGPA or HS GPA. Rather, one's gender is the first predictor of whether one will enroll in Workgroup. Though less than a quarter of all APPM 1350 students are women, about 50% of these women enroll in GEEN 1350, compared to only 17.9% of men. Since men outnumber women 3:1 in APPM 1350, they still make up 101 of the 184 GEEN 1350 students, or 54.9%.

After gender, HS GPA is the next biggest predicting factor for women enrolling in GEEN 1350. Only 29.0% of women with a HS GPA less than 3.94 or missing HS GPA enroll in GEEN 1350, while 60.7% of the 107 women with a HS GPA greater than 3.94 enroll in GEEN 1350. Since Workgroup is intended for weaker students in Calculus who need the extra support, we would expect the opposite result. Here we have the academically *stronger* women enrolling GEEN 1350 while those who potentially *need* the extra support are opting out. This is explained by the BOLD center's requirement of their scholarship students to enroll in Workgroup.

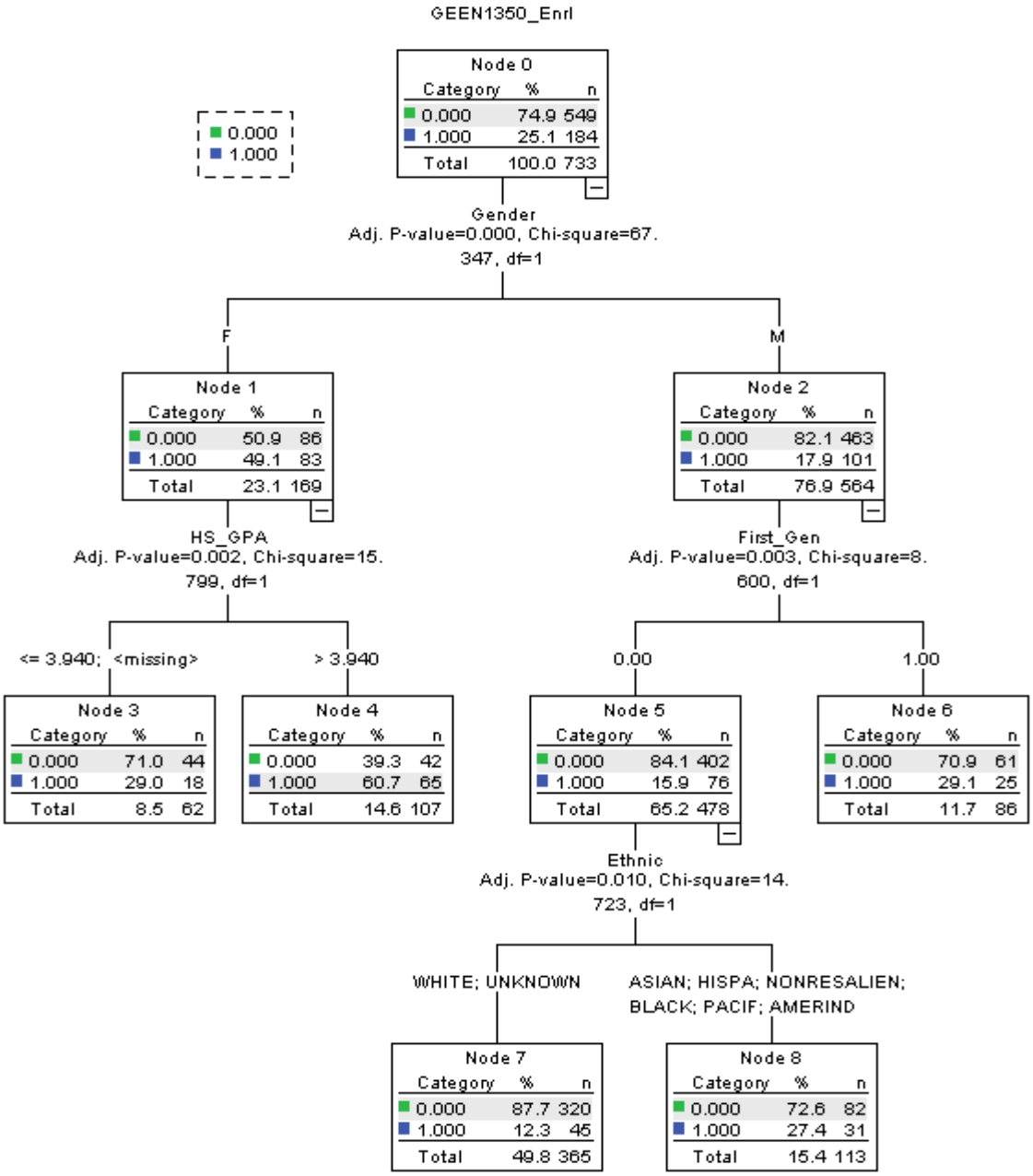

Figure 2.7: AnswerTree: Predicting factors for enrollment in Calculus 1 Workgroup

The second best predictor for men is first-generation status. 29% of first generation males enroll in GEEN 1350, while 15.9% of non-first generation males enroll. Non-first generation males are next best predicted by their ethnicity. White or otherwise unknown ethnicity students are 12.3% likely to enroll, while students of all other ethnicities are 27.4% likely to enroll in GEEN 1350. Since the BOLD Center actively recruits a diverse body of students, including first-generation and minority students, a likely explanation for this finding is that many of these male students are required by BOLD to enroll in Workgroup.

Comparing Workgroup and Non-Workgroup Students Table 2.2 shows a significant difference in PGPA between GEEN 1350 students and non-Workgroup students; for all students, for only men, and for only women. The fact that women come in with a higher mean PGPA is consistent with what we see in Figure 2.1. Of the five variables in this table, PGPA is the only one with a significant difference between Workgroup and Non-Workgroup students. This means that incoming Workgroup students start the semester with a significantly higher PGPA than non-Workgroup students, but then end the semester with no significant difference from the non-Workgroup mean course-grade in APPM 1350.

To have a clearer look at the impact of Workgroup on Calculus 1 performance, Table 2.3 shows the results of a T-test on Workgroup versus non-Workgroup students' course-grades, stratified by PGPA and gender. There are 270 total students involved in this test: 135 Workgroup students, 135 Non-Workgroup students. Of these 135 students in each group, 80 are male and 55 are female. We see that there is no significant difference in mean course grade between Workgroup and Non-Workgroup students, even when these students have identical PGPAs. This result holds for all three groups: all students, just mean, and just women. For women, the course mean is almost identical between the two groups: 2.76 for Workgroup women versus 2.80 for non-Workgroup women. Workgroup men, however, show a lower course mean than non-Workgroup men: 2.42 versus 2.72. This means that Workgroup men tend to do worse in Calculus 1 than non-Workgroup men, though the difference is not quite significant, with a p-value of .083.

The difference in results between men and women likely relates to attitude. Women who are required to enroll in Workgroup tend to have a better attitude toward Workgroup than men in the same position. We investigate attitude by means of survey questions in Chapter 3.

Table 2.2: The following table shows the results of T-tests for several predicting factors and course-grade for Calculus 1 (APPM 1350) and Calculus 2 (APPM 1360). The two groups are Workgroup students and Non-Workgroup students.

	Workgroup Mean	N	Non-Workgroup Mean	N	p-value
PGPA	3.41	165	3.28	459	.000
PGPA (men)	3.36	84	3.27	387	.004
PGPA (women)	3.45	81	3.34	72	.005
APPM1350_Grade	2.62	178	2.492	494	.184
APPM1360_Grade	2.63	138	2.508	349	.198
AP_Hrs	12.5	132	11.2	356	.275
ALEKS_Score	81.4	173	82.0	476	.599
AST_Score	23.978	181	23.986	503	.388

Table 2.3: The following table shows the results of T-tests on random sample of students course-grades, stratified by PGPA and gender. There are 270 total students involved: 135 Workgroup students, 135 Non-Workgroup students. Of these 135 students in each group, 80 are male and 55 are female.

	N	Mean PGPA	Workgroup Mean	Non-Workgroup Mean	p-value
All	135	3.45	2.56	2.75	.121
Women	55	3.49	2.76	2.80	.823
Men	80	3.42	2.42	2.72	.083

Table 2.4 shows results from an ANOVA test on PGPA between required Workgroup students (Group 1), non-required Workgroup students (Group 2), and non-Workgroup students (Group 3). Since the test had a p-value of .000, showing a significant difference in mean PGPA, we also look at the Post-Hoc Tukey HSD results in Table 2.6 to determine which means are different from the others. Each row of Table 2.6 compares each group of students with each remaining group. We see that Group 1 (required students) have a significantly different mean from both Group 2 and Group 3. From Table 2.4, we see that Group 1's mean is *higher* than both Groups 2 and 3. We also see that Groups 2 and 3 do not have significantly different mean PGPAs. This means that required students start the semester with significantly higher PGPAs than both non-required Workgroup

students *and* non-Workgroup students.

Table 2.4: This table shows the ANOVA results for mean PGPA between three groups of students: those required to enroll in GEEN 1350 (1) , those enrolled in GEEN 1350 but not required (2), and those not required nor enrolled in GEEN 1350 (3).

	N	Minimum	Maximum	Mean	Std. Deviation
1	64	3.04	3.68	3.4777	.13694
2	42	2.56	3.65	3.3429	.26081
3	333	2.47	3.71	3.3423	.24162
Total	439	2.47	3.71	3.3621	.23580

Table 2.5: Below are the Tukey HSD results, showing which groups specifically are significantly different. Note, for example, that Group 2 is significantly different from Group 1, but not from Group 3.

		Mean		95% Confidence Interval	
I (Q1)	J (Q1)	Difference (I-J)	Sig.	Lower Bound	Upper Bound
1	2	.13480*	.010	.0267	.2429
	3	.13540*	.000	.0611	.2097
2	1	-.13480*	.010	-.2429	-.0267
	3	.00060	1.000	-.0885	.0897
3	1	-.13540*	.000	-.2097	-.0611
	2	-.00060	1.000	-.0897	.0885

AST score versus ALEKS score[1] The AST test is administered during the first recitation of the semester for Calculus 1 students. This means that students who do not have an AST score most likely skipped the first week of recitation, moved down to Calculus 1 from Calculus 2, or moved up to Calculus 1 from pre-calculus or year-long calculus. The ALEKS test is taken online, thus students take it on their own time before starting at CU. It is an adaptive test, meaning it is very individualized. All incoming engineering students are strongly recommended to take the ALEKS. Therefore, missing ALEKS scores represent students who chose not to take it, or otherwise were unaware of the test.

We note that while AST score is the best predicting factor for Calculus 1 course grade in Figures 2.4, 2.5 and Figure 2.6, ALEKS Score did not show up as predicting factor any AnswerTree.

[1] This section is tangential to the main study of this thesis, though contains valuable information for the Applied Math department, and for future research in this area.

Two subsections, Numbers and Polynomials, came up, but not the overall ALEKS score. Table 2.6 shows a correlation matrix between ALEKS score, AST score, and course-grade in Calculus 1 and 2.

We see in Table 2.6 that there is a strong correlation between the ALEKS Score and AST Score, as well as between each of these scores and Calculus 1 and 2 course-grades. This is why AST and ALEKS are used to place students in Calculus. However, as seen in Table 2.2, there is no significant difference ALEKS Score nor AST score between Workgroup and Non-Workgroup students. The reason for this is most likely due to such a higher proportion of students who are required to take Workgroup. These students, who have a higher predicted GPA than do non-required students, most likely bring up the AST score average of Workgroup students.

Figure 2.8 is a scatterplot of AST score versus ALEKS score. We see a large population in the upper right corner, with mostly A to B- range students (indicated by red triangles). We also see several students in the C+ to C- range and students who fail or withdraw who scored greater than a 75 on the ALEKS but scored below an 18 on the AST exam. Since the ALEKS test is not proctored but the AST is proctored, this could indicate cheating. ALEKS will be required for all students this coming fall, which is a good first step, but we also believe that the ALEKS should be also proctored in the future.

Given that the ALEKS test is on a larger scale than the AST, and that it is an adaptive test, it *should* be a better predictor of Calculus performance than the ALEKS. This is not the case. AnswerTree finds AST score to be the best predictor for Calculus 1 course grade. Perhaps when ALEKS is not only required (this fall) but also proctored, it will be a better predictor than it currently is and then the AST test.

2.3 Section Summary

Given the purpose of Workgroup, we would expect several things. First of all, since Workgroup is intended for mathematically weaker students who need extra support, we would expect Workgroup students to have lower PGPAs than non-Workgroup students. We also might think

Table 2.6: This table shows the correlations between ALEKS Score, AST Score and Calculus 1 course-grade. A double asterisk indicates significance at the .01 level.

		ALEKS_Score	Calculus 1 Grade (Fall)	Calculus 2 Grade
AST Score	Pearson Correlation	.348**	.532**	.412**
	Sig. (2-tailed)	.000	.000	.000
	N	618	637	474
ALEKS Score	Pearson Correlation	1	.310**	.234**
	Sig. (2-tailed)		.000	.000
	N	649	612	464
Calculus 1 Grade (Fall)	Pearson Correlation		1	.759**
	Sig. (2-tailed)			.000
	N		672	487
Calculus 2 Grade (Spring)	Pearson Correlation			1
	Sig. (2-tailed)			
	N			487

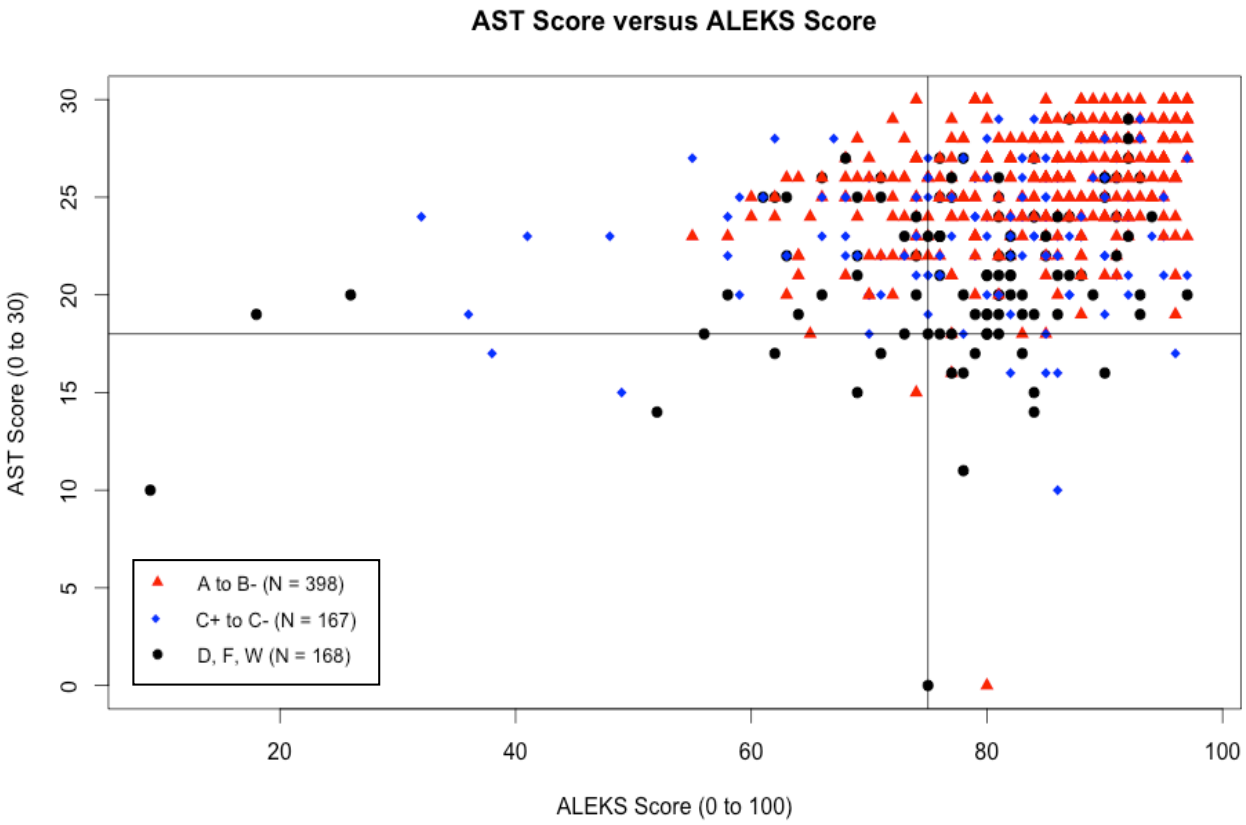

Figure 2.8: This scatterplot plots AST score versus ALEKS score, where AST ranges from 0 to 30, and ALEKS ranges from 0 to 100. The points are coded by course grade (by color and symbol), as indicated by the legend. A vertical line is at ALEKS score = 75 because students are recommended to take Workgroup or year-long Calculus 1 if they score below a 76. A horizontal line is at AST Score = 18 because this is the threshold below which students are predicted to fail or withdraw from Calculus 1.

that required students, denied the option to opt out of Workgroup, would have the lowest mean PGPA of all. Lastly, we would hope that Workgroup students would do significantly better than non-Workgroup students when stratified by PGPA.

We see none of these results. Workgroup students start with a higher PGPA than non-Workgroup students. More specifically, required students have a significantly higher PGPA than non-required students (both those enrolled in Workgroup by choice, and those not enrolled in Workgroup). Further, there is no significant difference in mean course-grade in Calculus 1 between Workgroup and Non-Workgroup students. Workgroup is not making the difference we hope it to make.

As mentioned earlier, GEEN 1350 only became a requirement for scholarship students in the Fall of 2011. One explanation for why Workgroup students no longer have a significant improvement in course grade is that the course is now required for some students, and poor attitude due to requirement may have a negative effect on student engagement in GEEN 1350. We see this especially with men, where Workgroup males have a lower (though not significantly) course grade in Calculus 1 than their non-Workgroup male counterparts. As will be seen in Chapter 3, close to two thirds of Calculus 2 Workgroup students in the Spring of 2014 were required to take the course. We look deeper into the relationship between requirement and attitude in Chapter 3, based on student responses to several survey questions.

Chapter 3

The Roles of Attitudes, Orals, and Instructors in Calculus Workgroup

3.1 Methodology

3.1.1 Focus Groups

In the Spring of 2013, I invited several groups of students to participate in focus groups about Calculus Workgroup: all Workgroup students (from Calculus 1, 2 and 3), Workgroup teaching assistants (TA), and Workgroup learning assistants (LA, the undergraduate analog of a teaching assistant). Subsequently, I hosted three focus groups of students, ranging from 2 to 4 people, and one focus group of Teaching Assistants. The purpose of these was to get a raw sense of students' and teaching assistants' attitudes toward Workgroup, what they appreciated, and what frustrated them. First of all, this gave me insight on how Workgroup might be improved, and secondly informed the questions to include on a survey, which was administered to all Workgroup students, TAs and LAs in the Spring of 2014.

I recorded each focus group, transcribed them, and then coded them. I checked Inter-Reader Reliability with my co-advisor, Dr. Nelson, on the first transcription. Once my coding was deemed consistent with that of my advisor's, I coded the final three transcriptions on my own. The following themes emerged from the student focus groups:

(1) Facilitator matters - facilitator teaching methods; Learning Assistant versus Teaching Assistant

(2) Quality of Worksheets affects student attitudes

(3) Comments on Orals, including both praise and constructive criticism

(4) The desire to do homework in Workgroup

(5) Workgroup is too long

(6) Workmates affect productivity

(7) Choosing to enroll versus Requirement affects student attitudes

In light of these seven themes, I created student surveys for all Calculus Workgroup students to complete.

3.1.2 Surveys

This analysis of focus group transcripts led to 19 student survey questions that speak to the above themes. Questions aim to capture student attitudes toward Workgroup, Oral Assessments, and their facilitators (TA and LAs), and to get feedback from students as to how Workgroup may be improved. The themes of Homework and Length of Workgroup were not addressed in the survey. Though students expressed the desire to do homework during Workgroup, this is not part of the conception of Workgroup. Students also expressed the desire for a shorter meeting time, but the length of Workgroup is non-negotiable because of the necessity to fulfill the one-credit requirement, set by the university.

Students from each of three Workgroup courses (Calculus 1, 2, 3), 14 sections in total, took this survey in the week after their last midterm of the Spring 2014 semester. This included 60 Calculus 1 students, 110 Calculus 2 students, and 36 Calculus 3 students. The first survey question (Q1) is a True or False question, while questions 2 - 19 are on a Likert scale, ranging from A to E (please see Appendix C for the complete Student Survey). Written feedback from students regarding attitude and ideas for improvement are included in the survey, but are beyond the time scale of this study and are therefore left for future analysis.

3.1.3 Learning Assistant and Teaching Assistant Surveys

Two other surveys were generated from the four focus groups and were administered at the same time as the student surveys. One survey was given to Workgroup Learning Assistants ($N = 9$), the other was given to Workgroup Teaching Assistants ($N = 8$). These surveys focused more on how Workgroup can be improved in future semesters, observations, and comparisons between Workgroup and Calculus recitations (a required component of APPM 1350 that meets for 50 minutes per week with a recitation Teaching Assistant). These survey results are not analyzed in this study. For the Learning Assistant survey, Teaching Assistant survey, and information on findings from these surveys, please see Appendices D, E and F.

3.1.4 Survey Analysis

This dataset contains student survey answers from Calculus 1, 2 and 3 Workgroups. However, since spring Calculus 2 students will overlap with the Calculus 1 Fall 2013 dataset analyzed in Chapter 2, and since Calculus 2 is the in-sequence course in spring semesters, I discount Calculus 1 results for the most part. Due to the smaller class sizes and being out of sequence, I assume that the spring Calculus 1 student population is different from the in-sequence Calculus 1 students who take Calculus 1 in fall semesters.

The first step of analysis is to plot mean question responses. Because PGPA was significantly different between required and non-required students, the students are split by their response to Question 1; those who are required to enroll in Workgroup versus those who are not. I then run a T-test on each question to see if there is a significant difference in a given question's mean among required and non-required students.

Questions that show a significant difference in mean response with respect to requirement are merged with the Fall 2013 Calculus 1 dataset analyzed in Chapter 2. Once merged, the survey questions of significance are tested for correlation with Calculus 1 course-grade, Calculus 2 course-grade and PGPA.

Since required students (response of "1" on Question 1) proved to have a significantly higher PGPA than non-required GEEN 1360 students, as seen in Table 2.4, I also do another stratified random sample to compare performance in Calculus 2 (in Spring 2014). Students are again stratified by PGPA, but cannot be stratified by gender because sample sizes are too small (there are only six non-required women enrolled in Calculus 2 Workgroup in the dataset). Once stratified, I conduct an Independent Samples T-Test on these samples to determine whether there is a significant difference in APPM 1360 course-grade between required and non-required students.

Next, I test for a difference in attitude between Workgroups for different Calculus courses (Calculus 1, 2 and 3). To do so, I compare Calculus 3 mean survey responses to required Calculus 2 responses and non-required survey responses in turn via T-tests.

3.2 Results and Discussion

3.2.1 Calculus 2 Survey Responses

Figure 3.1 shows the question averages for Calculus 2 Workgroup, required versus non-required students. Table 3.1 is consistent with what we see visually in Figure 3.1: that there are some significant differences in average survey answers between required and non-required students, namely questions 15 through 19. Since these are averages of human survey responses, as opposed to objective quantitative data (i.e. course grade or HS GPA), we use the .10 significance level here. We can interpret the Calculus 2 Workgroup results as the following:

15. Non-required students believe that Workgroup helps them perform better on tests significantly more than do required students.

16. Non-required students believe that their worksheets (in Workgroup) help them understand test problems significantly more than do required students.

17. Non-required students believe that their worksheets (in Workgroup) help them improve their understanding of concepts significantly more than do required students.

18. Non-required students have found Workgroup to be more helpful as the semester has progressed significantly more than have required students.

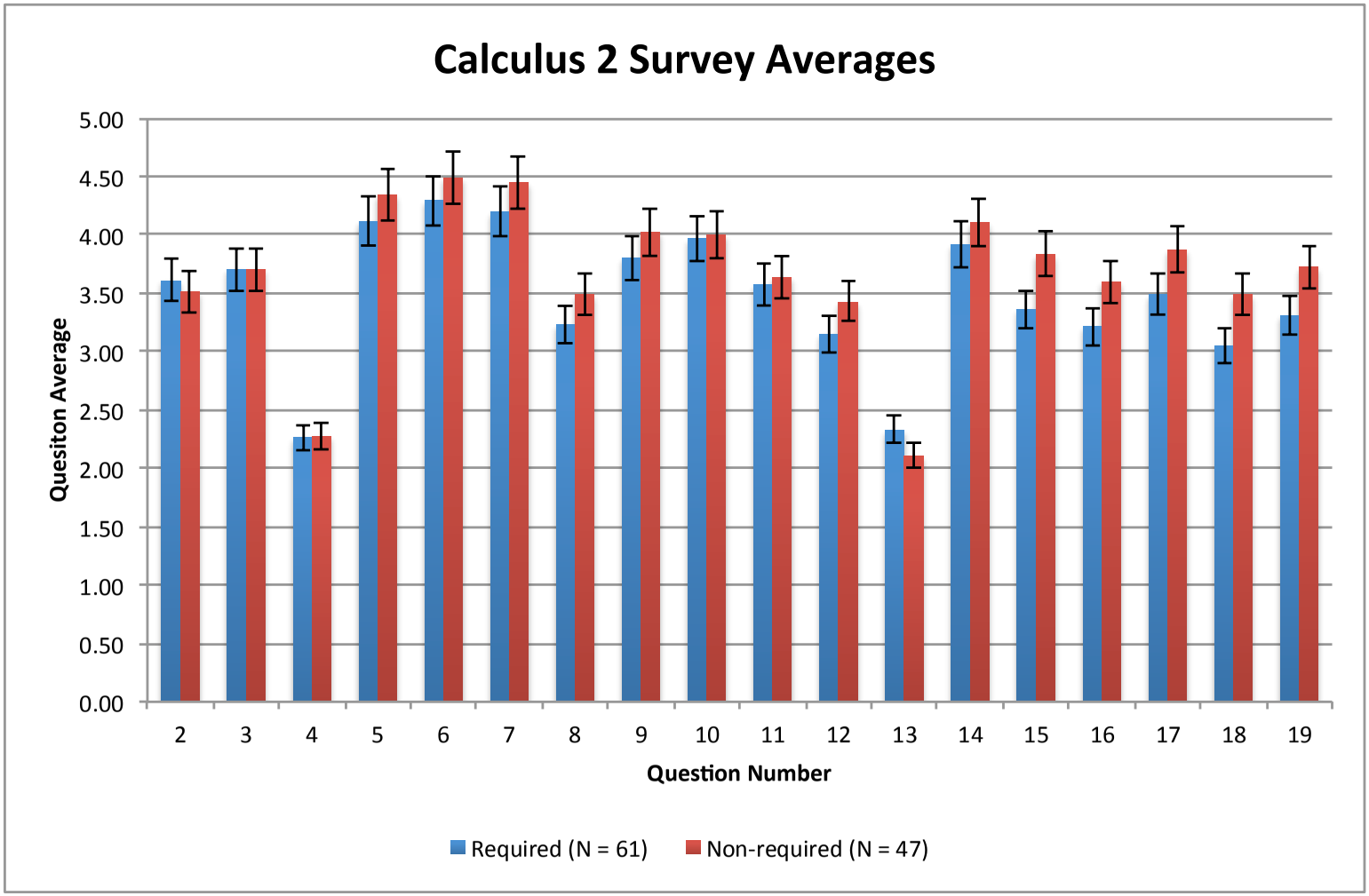

Figure 3.1: For each question (2 through 19), the required mean response and non-required mean response are shown. The error bars show a 95% confidence interval.

Table 3.1: This table shows the T-test results from comparing required Calculus 2 Workgroup students to non-required Workgroup students by the survey responses that showed a significant difference. Since this data is very qualitative in that it involves people's responses, significance is tested at the .10 level.

Q1	Required Mean (N = 61)	Non-Required Mean (N = 47)	p-value
Q15	3.36	3.78	0.027
Q16	3.21	3.60	0.053
Q17	3.49	3.87	0.051
Q18	3.05	3.49	0.044
Q19	3.31	3.72	0.074

19. Non-required students believe they will get a better grade in the course due to taking workgroup significantly more than do required students.

We see that there is a significant correlation between a student's attitude toward Workgroup, and their requirement to enroll. Students who are required to enroll in the course tend to have a poorer attitude toward Workgroup. They believe significantly less than non-required students that Workgroup helps them, that worksheets in Workgroup help them, and that Workgroup becomes more helpful with time.

Questions 15 and 19 are merged with the Fall 2013 Calculus 1 dataset (analyzed in Chapter 2). We look at correlations between these two questions, PGPA, Fall Calculus 1 course-grade and Spring Calculus 2 course-grade. Table 3.2.1 shows the results of this correlation test. The major result of this test is that Questions 15 and 19 are *not* significantly correlated with course-grades in Fall Calculus 1 nor Spring Calculus 2. This is contradictory to what is seen in literature. Multiple studies show a strong correlation between attitude and performance ([7, 20, 21]).

Since Table 3.2 shows a negative correlation between Q1 and PGPA, meaning that those that are required start with a higher PGPA than non-required students, I conduct a stratified random sample of students, stratified by PGPA. Table 3.3 gives the results of this T-test comparing these two groups of students. We see that the two populations have identical Calculus 2 mean course-grades (though very different standard deviations), meaning there is no significant difference in

Calculus 2 grade[1] . Note that the course-grade average for both groups is greater than the Spring Calculus 2 average course grade for Workgroup students found in Table 2.2. This is most likely due to sample sizes that are too small to give us much information: there are 138 Spring Calculus 2 students, yet this table only includes 58, or 42% of them.

In looking at Figure 3.1, we can see student responses to survey questions overall. The first result to note is which questions have a mean below 3, meaning that students disagree on average. Students tended to disagree with Questions 4 and 13:

4. My TA is more likely than our LAs to just work problems for us.
13. The only value of Orals in workgroup is to take a break from worksheet.

This means that Calculus 2 Workgroup students tend to believe their TA is *not* more likely to just work problems for them, and that Oral Assessments have more value than merely to take a break from their worksheet. These are the two questions with which we would hope students disagree.

The rest of the questions pertain to comfort around people in workgroup (group-mates, LAs, TA), value of Oral Assessments, and attitude toward Workgroup. The average for questions 5, 6 and 7 are strictly above 4 for both required and non-required students. This means that, on average, students agree with the statements "*I feel comfortable asking questions of my TA,*" *"I feel comfortable asking questions of my LAs,"* and *"I feel comfortable asking questions of my group-mates in Workgroup*". Students' agreement with these statement suggests that Iannone and Simpson's concern about anxiety is a nonissue with Orals in the Workgroup setting [9].

We also see the average for questions 2, 3, 8 - 12, and 14 - 19 are between 3 and 4 (Neutral and Agree). For Questions 14 - 19, which all pertain to attitude towards Workgroup, this is an encouraging finding. Others are less promising, however. The average agreement for the statement *It is helpful if the TA/LA solves the problem for me* (Q8) is above neutral, though we would hope

[1] Note: Though very improbable, this is statistically possible given that there are only 29 observations per group (non-required and required)

Table 3.2: Below is a correlation matrix between five variables. Significance at the .05 is denoted by a single asterisk, while significance at the .01 level is denoted by double asterisks. The number of students included are 102, with the limiting variable being Spring Calc 2 grade.

	Q15	Q19	Fall Calc 1 Grade	Spring Calc 2 Grade	PGPA
Q15	Pearson Correlation	.825**	-.121	.016	-.256**
	Sig. (2-tailed)	.000	.202	.873	.008
Q19	Pearson Correlation	1	-.106	-.026	-.222*
	Sig. (2-tailed)		.266	.797	.024
Fall Calc 1 Grade	Pearson Correlation		1	.759**	.495**
	Sig. (2-tailed)			.000	.000
Spring Calc 2 Grade	Pearson Correlation			1	.453**
	Sig. (2-tailed)				.000

Table 3.3: The following table shows the results of a T-test on random sample of students Spring Calculus 2 course-grades, stratified by PGPA. There are 58 total students involved: 29 required Workgroup students and 29 non-required Workgroup students. The mean PGPA of each group is 3.49.

Required Mean	Required St. Dev.	Non-Required Mean	Non-Required St. Dev.	p-value
3.00	.747	3.00	1.472	1

for disagreement. However, students also were above neutral on average in response to *I prefer if the TA/LA asks leading questions that help me figure out the answers myself* (Q2) as well. Student agreement with this statement was slightly higher (though not significantly higher) than their agreement with Q8. These two statements are contradictory, so students' agreement with both is quite confounding.

Q12 is the statement, *I find Oral Review Sessions (the week before tests) more helpful than Orals in workgroup.* On average, students answer above neutral for this statement as well. Considering their responses to Questions 9, 10 and 11 were above neutral, and they all pertain to Orals (i.e. *I think Orals are an important part of Workgroup*), this suggests that students do value Orals Assessments.

3.2.2 Comparing Calculus 1, 2 and 3 Workgroups

Figure 3.2 compares Calculus 3 Workgroup student responses to those of Calculus 2 required and Calculus 2 non-required students. We see a significant difference in several questions. For Questions 8 and 9, non-required Calculus 2 Workgroup students have a significantly higher response average, which we can interpret as the following:

> 8) Non-required Calculus 2 Workgroup students believe that it is helpful if the TA/LA solves the problem for them significantly more than do Calculus 3 Workgroup students.
>
> 9) Non-required Calculus 2 Workgroup students believe that Orals are an important part of Workgroup significantly more than do Calculus 3 Workgroup students.

The result for Question 9 suggests that non-required Calculus 2 Workgroup students value

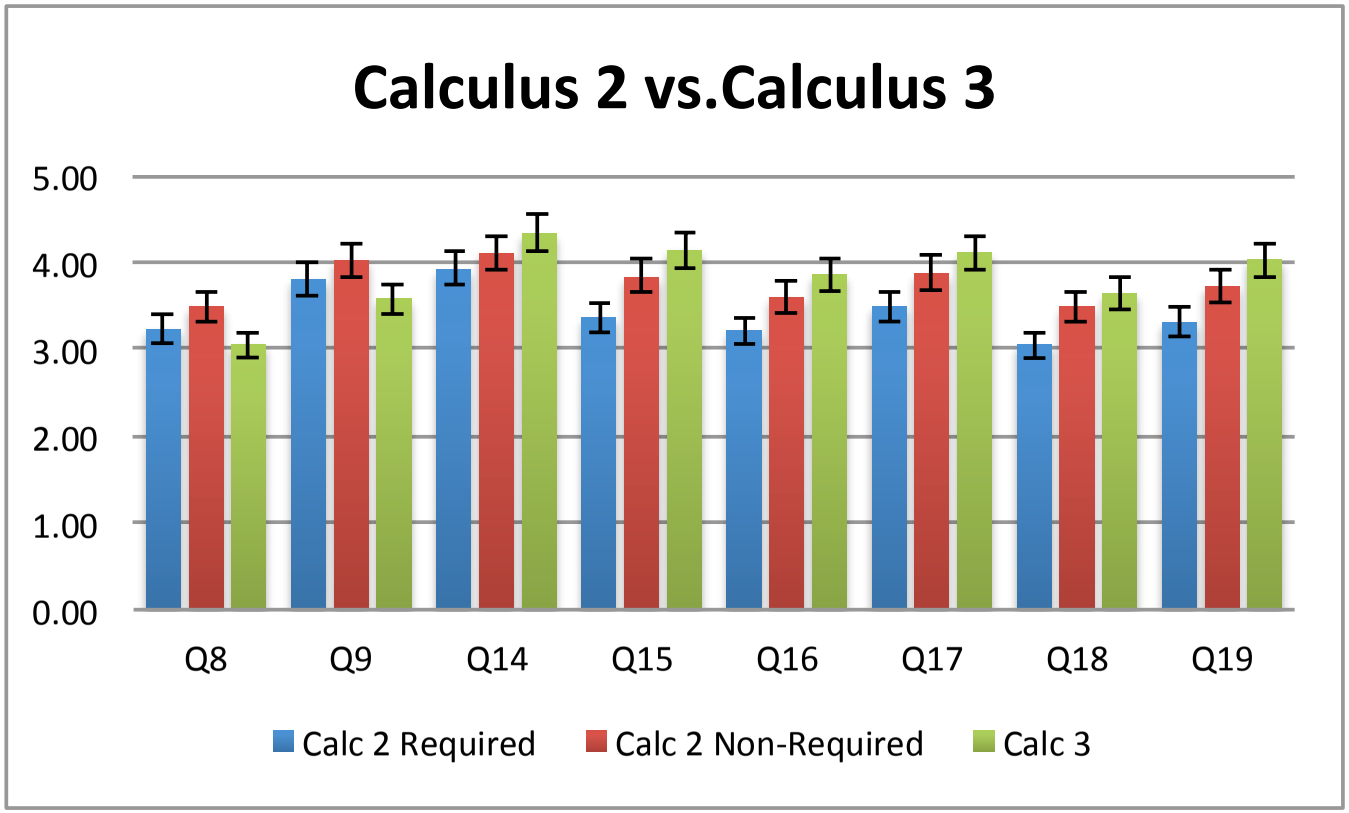

Figure 3.2: This graph contains three groups: Calculus 3 Workgroup students, required Calculus 2 students, and non-required Calculus 2 students. The first two questions demonstrate a significant difference between Calculus 2 non-required Workgroup students and Calculus 3 Workgroups students, while the last six show a significant difference between required Calculus 2 Workgroup students and Calculus 3 Workgroup students. Note that the error bars reflect a 95% confidence interval for each question.

Oral Assessments more than Calculus 3 Workgroup students do, on average. This is likely due to the fact that Calculus 3 Workgroup has less developed weekly Orals concept questions. Calculus 2 Orals questions were written in 2007 and have been revised for seven years while Calculus 3 Workgroup began only two years ago in 2011. In contrast to Calculus 2 Orals questions, Calculus 3 Orals questions are written in an ad-hoc manner by teaching assistants.

The result for Question 8 is not easily explained. This statement is not necessarily contradictory to Question 2, where students state whether they find it more helpful when the TA/LA asks leading questions to help them figure out the answer. However, the fact that non-required students agree with Question 8 significantly more so than do Calculus 3 students, and that there is no significant difference between *required* Calculus 2 students and Calculus 3 students, is confounding. Perhaps this question should instead read "I prefer my TA or LA to solve the problem for me", which is a stronger statement than merely "I find it helpful". This would be more informative for future surveys.

We also see the following in Figure 3.2: Calculus 3 Workgroup students believe

14) Workgroup helps them understand some of the concepts that are confusing in class,

15) Workgroup helps them perform better on tests,

16) completing the worksheet (in Workgroup) helps them understand the problems they need to solve on the tests,

17) the worksheets in Workgroup help them improve their understanding of concepts,

18) Workgroup was more helpful as the semester progressed, and

19) they will get a better grade in the course because they are taking Workgroup

significantly more than do Calculus 2 students who are required to take Workgroup.

The above six questions suggest that Calculus 3 Workgroup students in general have a better attitude toward Workgroup than do non-required Calculus 2 Workgroup students. There was no significant difference between required and non-required students for Calculus 3 Workgroup students, indicating a more mature student body than Calculus 2 Workgroup students. Calculus 3

students have been exposed to the university setting for longer, and thus might value resources such as Workgroup more. We can see visually in Figure 3.2 that non-required Calculus 2 Workgroup students average in between required Calculus 2 students and all of Calculus 3 Workgroup students for each of Questions 14 - 19, indicating that the attitudes of non-required students is closer to that of the Calculus 3 students than are the required Calculus 2 students.

3.3 Survey Summary

Analysis of the student survey revealed significant differences between Calculus 2 required Workgroup students and Calculus 2 non-required Workgroup students on several questions. Non-required students tend to agree more strongly with questions pertaining to attitude about Workgroup, such as: *I believe workgroup helps me perform better on tests*; *Completing the worksheet helps me understand the problems I need to solve on the tests*; *The worksheets in Workgroup help me improve my understanding of concepts*; *As the semester has progressed, I have found Workgroup to be more helpful*, and *I believe I will get a better grade in the course because I am taking Workgroup.*

The survey results reveal several other factors. One is that, on average, Calculus 2 Workgroup students feel comfortable around their group mates, TA and LAs. This means that Workgroup is a comfortable learning environment for students, and that anxiety is probably not a concern with respect to Oral Assessments in Workgroup. The survey also showed that Calculus 2 Workgroup students believe Orals to be an important part of Workgroup.

Lastly, though the data suggest a significant relationship between requirement to enroll in Workgroup, and attitude toward Workgroup, we do not find a significant difference in course grade, even when students start with the same PGPA. This finding is contradictory to literature, and may be a result of small sample sizes and randomness.

Chapter 4

Conclusions

Our quantitative data tells us that, in the Fall of 2013, enrolling in Calculus 1 Workgroup did not significantly impact one's course-grade in Calculus 1. Our qualitative data further told us that there is a significant difference in responses to attitude-related questions between students who are required to enroll in Workgroup versus those who choose to do so. We found no significant difference, however, in Calculus 1 course-grade between required workgroup students, non-required workgroup students, and non-workgroup students.

In 2003, before Workgroup was required of anyone, Cooley found that not all students who take GEEN 1350 showed a significant improvement in their Calculus 1 grade, compared to non-workgroup students. However, he found students who scored in the 19-22 range on the assessment exam did show a significant improvement [5]. This is the range of students targeted for workgroup. In 2003, workgroup was doing its job for these students. Now however, we note a difference in student body, given the requirement of some students to enroll in Workgroup. Does this requirement make a significant difference on the impact of Workgroup?

The fact that attitude is statistically tied to performance and found in a multitude of studies makes the study of these questions well worth pursuing [7, 20, 21]. At the University of Colorado Boulder, Calculus Workgroup used to improve students' grades significantly in Calculus courses [5]. Since the course became mandatory for some students, we learned that the course no longer significantly helps students' grades. Given the vast amount of literature on attitude and performance, I believe the requirement of workgroup had a negative impact on its success, and the course should

be made strictly voluntary once again.

As opposed to requiring the course that is shown to make a difference, energy should be spent on building student motivation and confidence. It takes intentionality and great care on the educator's part to motivate students. As Scarpello suggests, teachers need to "reduce math anxiety and encourage students to pursue challenging courses." [21]. Students need confidence in mathematics, because confidence in one's own abilities can significantly help one's performance [7]. Therefore, weaker students should still be strongly advised to take workgroup, but they ultimately should make the decision. Perhaps then students who enroll will find they value Workgroup, and upon hearing good feedback, others, particularly those in the 19 - 22 AST range ([5]), will make the choice to enroll.

4.1 Future Directions

Several things are changing with respect to Calculus and Workgroup at CU going into the 2014 - 2015 academic year. First of all, the BOLD center will no longer require its students to enroll in Workgroup; it will be completely voluntary. Secondly, the ALEKS pre-assessment test will be mandatory for all students. In light of these two changes, it would be extremely valuable to repeat this study and compare it to the findings of this thesis. Looking at the same variables would tell us more about the relationship between attitude and performance, and ALEKS may or may not turn out to be a better predictor variable than it was this past year. Given that AST score has proven to be a good predicting factor of Calculus performance in past years ([11, 5, 13]), perhaps the ALEKS cutoff for those recommended to enroll in Workgroup (currently at 75%) should be calibrated by students' corresponding AST scores. In addition to ALEKS being mandatory for all students, ALEKS should be proctored (as AST is). This would prevent potential cheating that can occur in unsupervised settings, and therefore could make ALEKS score a better predicting variable for Calculus performance.

It would also be ideal to collect a larger dataset that is a cross-section of all calculus courses. Given that we found a range of attitudes, depending on calculus course (namely Calculus 3 Work-

group students demonstrated more positive attitudes toward workgroup than their Calculus 2 counterparts), being able to analyze course-grade based on attitude would be invaluable. This would allow us to address questions like, *is there a correlation between believing that one will perform better in calculus by enrolling in workgroup, and actually performing better in calculus?* Comparing the impact of Calculus 2 Workgroup to the impact of Calculus 3 Workgroup on course-grade, with a positive attitude being the difference between the two groups, would address this question.

It also would be beneficial to make this into a longitudinal study. Rather than only collecting data in the fall, data should be collected for four semesters in a row. In this way, we would have attitude and performance data on students through the whole Calculus sequence. Four semesters would include students who take the year-long Calculus 1 sequence as well. Further, students who complete the sequence *in-sequence*, that is, Calculus 1 in the fall, Calculus 2 in the spring, and Calculus 3 in the fall, could be compared to students who take the courses out-of-sequence (spring, fall, spring). Lastly, this data should also be compared to the dataset used in this study. In this way, where Workgroup was required in one dataset but not in the other, the role of requirement can be analyzed. Overall, a multitude of questions would be addressed by a dataset such as this.

Bibliography

[1] The BOLD Center: Mission and Vision. http://bold.colorado.edu/index.php/about-bold/missionandvision/, 2012.

[2] Rose Asera. Calculus and community: A history of the Emerging Scholars Program. The College Board, 2001.

[3] Nathan D. Balk. Concept questions in calculus 1: Identifying the misconceptions and difficulties of students, 2007.

[4] D. Biggs, B. de Ville, and E. Suen. A method of choosing multiway partitions for classification and decision trees. Journal of Applied Statistics, 18:49–62, 1991.

[5] Daniel Cooley and Anne Dougherty. Prediction of Student Performance in Freshman Calculus, January 2003.

[6] J. Hiebert. Relationships between Research and the NCTM Stankards. Journal for Research in Mathematics Education, 30(1):3–19, January 1999.

[7] J. House. The predictive relationship between academic self-concept, achievement expectancies, and grade performance in college calculus. Journal of Social Psychology, 135(1):111–112, 1995.

[8] Teri J; Hsu, Eric; Murphy and Uri Treisman. Supporting high achievement in introductory mathematics courses: what we have learned from 30 years of the Emerging Scholars Program. Making the Connection: Research and Teaching in Undergraduate Mathematics Education, MAA Notes, 73:205–220, 2008.

[9] P Iannone and A Simpson. Oral assessment in mathematics: implementation and outcomes. Teaching Mathematics and its Applications, 31(4):179–190, 2012.

[10] Paola Iannone and Adrian Simpson. Performance assessment in mathematics: Preliminary empirical research. Mapping University Mathematics Assessment Practices, page 127, 2012.

[11] Anna C. Karplus. Prediction of Student Performance in Calculus 1 using Decision Tree Models. Master of Science, Department of Applied Mathematics, University of Colorado at Boulder, 1998.

[12] G.V. Kass. An exploratory technique for investigating large quantities of categorical data. Applied Statistics, 19(2):119–127, 1980.

[13] Jenny McColl and Anne Dougherty. Prediction of Student Performance in Freshman Calculus, August 2000.

[14] M. A. Nelson. Reforming the Teaching of Calculus: Oral Exams, 2004.

[15] M. A. Nelson. A Reform Approach to Calculus Instruction: Effects on Retention, Grades and Understanding. PhD thesis, University of Colorado, Boulder, August 2005.

[16] M. A. Nelson. Oral assessments: Improving retention, grades, and understanding. PRIMUS, 21(1):47–61, 2010.

[17] University of Colorado at Boulder. CU's Applied Math Department to Study Learning Through Oral Assessments with New NSF Grant, November 2008.

[18] University of Colorado at Boulder. Math Performance is Cool. http://www.colorado.edu/engineering/academic-programs/math-performance-cool, 2013.

[19] David Pimm. Speaking mathematically: Communication in mathematics classrooms. Routledge & Kegan Paul London, 1987.

[20] Laura Pyzdrowski, Ye Sun, Reagan Curtis, David Miller, Gary Winn, and Robin Hensel. Readiness and attitudes as indicators for success in college calculus. International Journal of Science and Mathematics Education, 11(3):529 – 554, 2013.

[21] G. Scarpello. Helping students get past math anxiety., 2007.

[22] Anna Sfard, Pearla Nesher, Leen Streefland, Paul Cobb, and John Mason. Learning mathematics through conversation: Is it as good as they say?, 1998.

[23] Uri Treisman. A model academic support system. Improving the Retention and Graduation of Minorities in Engineering, pages 55–65, 1985.

[24] Barbara B. Ward, Stephen R. Campbell, Mary R. Goodloe, Andrew J. Miller, Kacie M. Kleja, Eninka M. Kombe, and Renee E. Torres. Assessing a Mathematical Inquiry Course: Do Students Gain an Appreciation for Mathematics? PRIMUS, 20(3):183–203, 2010.

[25] Mary Worthley. A mixed methods explanatory study of the failure/drop rate for freshman STEM calculus students. PhD thesis, Colorado State University, 2013.

Appendix A

Fall 2013 Calculus 1 Students: Dataset Variables

The following are the variables included for each student in the Fall 2013 Calculus 1 Students dataset, along with short descriptions of each.

(1) **HS_GPA:** High School grade point average

(2) **ACT_C:** ACT Composite score (sum of highest components)

(3) **ACT_E:** ACT English (highest component)

(4) **ACT_M:** ACT Mathematics (highest component)

(5) **ACT_R:** ACT Reading (highest component)

(6) **ACT_S:** ACT Science (highest component)

(7) **SAT_T:** SAT total (sum of highest components)

(8) **SAT_M:** SAT Mathematics (highest component)

(9) **SAT_V:** SAT Verbal (highest component)

(10) **HS_Calc:** High School Calculus hours

(11) **Entry_Term:** Year and term (summer, spring, fall)

(12) **Entry_Type:** Freshman, transfer or non-degree

(13) **Transfer_GPA:** If transfer student, grade point average

(14) **Transfer_Hrs:** If transfer student, transfer credit hours

(15) **AP_Hrs:** Number of Advanced Placement credits

(16) **Index_Score:** Calculated from HS GPA combined with ACT or SAT score

(17) **HS_Percentile:** High School percentile

(18) **PGPA:** Predicted grade-point average based on high-school GPA and ACT Math or SAT Math score. If both ACT and SAT data are available for a given student, the higher of the two calculated PGPAs is used.

(19) **Gender**

(20) **Ethnic:** Ethnicity

(21) **Mom_Educ_Lvl:** Mother's highest level of education

(22) **Dad_Educ_Lvl:** Father's highest level of education

(23) **First_Gen:** Whether student is first generation student

(24) **Fam_Rsrc_Quartile:** Family resource quartile

(25) **Residency:** Colorado resident or non-resident

(26) **CumGPA_Fall13:** Cumulative grade point average at the end of Fall 2013 term

(27) **Class_Lvl_Fall13:** Class level at the end of Fall 2013 term

(28) **APPM1350_Grade:** Course grade in Calculus 1 for Engineers in Fall 2013 term

(29) **GEEN1350_Enrl:** Whether student enrolled in Calculus 1 Workgroup

(30) **GEEN1350_Grade:** Course grade in Calculus 1 Workgroup (P/F)

(31) **APPM1360_Enrl:** Whether student enrolled in Calculus 2 for Engineers

(32) **GEEN1360_Enrl:** Whether student enrolled in Calculus 2 Workgroup

(33) **ALEKS_Score:** Department pre-assessment algebra exam, scale of 0 - 100

(34) **ALEKS_Numbers:** ALEKS numbers score, scale 0 - 100

(35) **ALEKS_Equations:** ALEKS equations score, scale 0 - 100

(36) **ALEKS_Functions:** ALEKS functions score, scale 0 - 100

(37) **ALEKS_Polynomials:** ALEKS polynomials score, scale 0 - 100

(38) **ALEKS_Rational_Expressions:** ALEKS rational score, scale 0 - 100

(39) **ALEKS_Radicals:** ALEKS radicals score, scale 0 - 100

(40) **ALEKS_Logarithms:** ALEKS logarithms score, scale 0 - 100

(41) **ALEKS_Trigonometry:** ALEKS trigonometry score, scale 0 - 100

(42) **AST:** CU algebra and trigonometry pre-assessment test score, scale 0 - 30

Appendix B

AnswerTree and the CHAID Algorithm

Given a dependent variable (in this case, APPM 1350 course grade), AnswerTree software begins with the entire dataset as the first node and tests all predicting factors as candidates to split the node. The variable with the strongest significance according to chi-squared (categorical associations) or F-statistic (continuous associations).

The Chi-Squared Automatic Interaction Detection (CHAID) methodology, introduced by Kass in 1980, was designed for a categorical dependent variable. Each predictor variable is cross-tabulated with the dependent variable, which uses χ^2 statistics. Categories with p-values greater than .05 (statistically insignificant) are merged until only one single pair remains. The dependent variable is then split by this predictor variable. This process is repeated with the remaining predictor variables until the stopping condition (number of node levels) is met or until no more variables are found to be significant [12].

The Exhaustive CHAID algorithm uses the same three processes: merging, splitting, and stopping. It is identical to CHAID in the splitting and stopping steps. However, exhaustive CHAID, put forth by Biggs in 1991, biases neither simple partitions nor predictor variables with many categories [4].

Appendix C

Student Survey

Before you answer any questions, please be sure to fill out your Student ID! If you do not know yours, ask your TA. Below are 19 questions. The first is True or false, and the rest are on the following spectrum:

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A	B	C	D	E

Please answer questions (2) to (19) using the spectrum above. Ask your TA if you have any questions.

(1) TRUE or FALSE: I have a scholarship that requires me to register for workgroup.

People in Workgroup

(2) I prefer if the TA/LA asks leading questions that help me figure out the answers myself.

(3) The students I work with in workgroup make a difference in how hard I work.

(4) My TA is more likely than our LAs to just work problems for us.

(5) I feel comfortable discussing problems with my group mates.

(6) I feel comfortable asking my TA questions in workgroup.

(7) I feel comfortable asking my LA(s) questions in workgroup.

(8) It is helpful if the TA/LA solves the problem for me.

Free write: Write one or two sentences about how you engage with your TA and each of your LAs.

Free write: Feel free to elaborate on your answer to any of the previous questions in the space below.

Oral Assessments (Orals)

(9) I think orals are an important part of workgroup.

(10) Orals help me see my own misconceptions.

(11) Orals are helpful because I can see how other students approach a problem.

(12) I find Oral Review Sessions (the week before tests) more helpful than Orals in workgroup.

(13) The only value of Orals in workgroup is to take a break from worksheet.

Free write: List something you like about Orals.

Free write: List what you might change about Orals.

Free write: Other comments on Orals:

General about Workgroup

(14) Workgroup helps me to understand some of the concepts that are confusing in class.

(15) I believe that workgroup helps me to perform better on tests.

(16) Completing the worksheet helps me understand the problems I need to solve on the tests.

(17) The worksheets in Workgroup help me improve my understanding of concepts.

(18) As the semester has progressed, I have found Workgroup to be more helpful.

(19) I believe I will get a better grade in the course because I am taking workgroup.

Free write: List the positive aspects of workgroup.

Free write: List the negative aspects of workgroup.

Free write: Give any suggestions you have for improving workgroup.

Appendix D

Learning Assistant Survey

Below are 10 questions. Please answer the first six using the following spectrum:

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A	B	C	D	E

(1) My two TAs structure Workgroup the same as one another.

(2) My two TAs handle attendance the same.

(3) My two TAs handle participation the same.

(4) I feel that I personally run my Orals sessions consistently between the two workgroups.

(5) I feel I help with worksheets consistently between the two workgroups.

(6) Orals is an important part of Workgroup.

Free write: List comments you have on variability between the two TAs you assist:

Free write: List one or two positive aspects of Workgroup.

Free write: Is there anything you would change to improve Workgroup?

Free write: Any other comments?

Appendix E

Teaching Assistant Survey

(1) Which course do you enjoy teaching more, workgroup or recitation? Why?

(2) Which course do you believe makes a bigger difference in students' understanding of callus material, workgroup or recitation? Why?

(3) Do you see a difference in student engagement with workgroup orals versus test review orals? Do you find one to be more effective than the other?

(4) Have you noticed a difference at all between students who choose to take workgroup, and those who are required to take workgroup for a scholarship?

(5) Do you like the structure of Calculus Workgroup: worksheets and orals?

(6) What do you think is the most helpful aspect of workgroup?

(7) Would you change anything about how workgroup is run?

(8) Any further questions or comments?

Appendix F

Learning Assistant and Teaching Assistant Survey Analysis

Nine Learning Assistants took the LA survey, and 8 Teaching Assistants took the TA survey. The LA survey has several Likert scale questions, and several free write questions, and focuses on the consistency of the facilitators across Workgroups. This includes the LA's self-perception of their own consistency in facilitating Orals and answering worksheet questions, as well as comparing two Teaching Assistants, since each LA helps with two workgroups. To compare LAs of different Calculus courses to each other (those of Calculus 1, 2 and 3), I do an ANOVA test on each question, where LAs are split by course. The two questions that emerge as significant are questions 4 and 6. Therefore, I look at responses to these questions individually.

4) I feel that I personally run my Orals sessions consistently between the two workgroups.

6) Orals are an important part of Workgroup.

Table F.1 results suggest that Calculus 1 and 2 LAs do believe that they run Orals sessions consistently across sections of Workgroup, while Calculus 3 LAs either disagree or are neutral

	Question 4	Question
Calculus 1 LAs	DDD	EEE
Calculus 2 LAs	DDEE	DDEE
Calculus 3 LAs	BC	BB

Table F.1: This table compares LA survey responses to Questions 4 and 6, based on Calculus course 1, 2 and 3.

(neither agree nor disagree). Question 6 results suggest that Calculus 1 and 2 LAs value Orals as a part of Workgroup, and Calculus 3 LAs do not.

As we start to analyze these results, we note that these are small sample sizes, and thus merely give us a basis to do further surveys and analysis in the future. These results are consistent with whether Workgroup students value Orals or not. We saw in Chapter 3 that non-required Calculus 2 Workgroup students value Orals significantly more so than Calculus 3 students. We believe this is because Calculus 3 Workgroup is a more recent course than Calculus 2 or Calculus 1 Workgroups. The Orals questions are less developed and seem to be less valued by Teaching Assistants. Therefore, LAs similarly value Orals less than their Calculus 1 and 2 LA counterparts.

Unlike the LA survey, the TA survey is all free write. The questions focus on the TA's preference for recitation versus Workgroup, since all TAs also teach recitation (a required component of Calculus lecture). Analysis of these surveys are extremely qualitative. We find varied responses to each question. Some TAs prefer recitation, while others prefer Workgroup. Some TAs, whether they prefer teaching Workgroup or not, find recitation to be a more effective teaching environment, while still others find Workgroup to be more effective. We find a significant difference in Calculus 2 student response to Question 9, how much students value Orals in Workgroup, based on their section of Calculus 2 Workgroup. It seems that Workgroup students who have TAs that prefer teaching in recitation tend to value Orals more than students of TAs who prefer to teach Workgroup. This result seems confounding, until one reads deeper into the student survey questions and realize they are not extremely informative. A student may respond less strongly to this question if they really value worksheets in Workgroup.

The takeaway of this is that perhaps the student survey questions should be rewritten to give more conclusive results. Instead of "I think Orals are an important part of Workgroup," perhaps we should ask, "I think Orals are *the most* important aspect of Workgroup". In addition to these changes, it would perhaps be beneficial to convert the Teaching Assistant survey into Likert scale,

so that over the course of several semesters, there would be enough survey data to make some conclusive statements about teaching assistants' perspective on Workgroup.