

# Evaluating an AP Calculus Programs Struggles: Lessons Learned and Changes for Improvement

Jeremy Zelkowski

Department of Curriculum & Instruction, The University of Alabama

This article presents the findings for a two-year evaluation study of a struggling calculus advanced placement (AP) program at a private K-12 school. This descriptive case study uses qualitative and quantitative data to pinpoint the problematic issues within the program, determine solutions, and make recommendations for change. Year-one transcript (2008-09) analysis indicated students who took the AP calculus AB exam saw their ACT-math (ACTm) scores decline nearly one full point per year from 2004 to 2009. Further, grade inflation was evident indicating assessments within the mathematics classrooms were weak or poorly aligned with AP expectations. Classroom observations and teacher interviews indicated low-level cognitive task teaching with little rigor and lower expectations in precalculus mathematics courses designed for AP preparation. Additionally, technology was not being used as an inquiry and exploratory tool but rather computationally. Student engagement was low and homework expectations for AP track students were minimal initially. Recommendations include addressing these findings through pedagogical change, professional development, and increased rigor. Year-two (2009-10) revealed that the newly instituted changes were accompanied by a strong improvement on the ACTm component; however, AP calculus exam results were similar to prior years. Math GPAs became more correlated with ACTm scores. Pedagogical shifts presented classroom dynamics resulting in increased rigor and expectations, along with higher student engagement and more proactive homework expectations.

## Introduction

Calculus enrollments in high schools across the U.S. have grown significantly since the mid-80s (Adelman, 1999, 2006; National Center for Education Statistics (NCES), 2010). College bound students are taking more mathematics now than ever before, but achievement tests, college admissions and placement tests indicate that many of these students are neither calculus-ready nor algebra-ready for college (Anthony, 2000; Aycaster, 2001; Cerrito and Levi, 1999; Duncan and Dick, 2000; Duranczyk and Higbee, 2006; Gupta et al., 2006; Ironsmith et al., 2003; Penny and White, 1998; Royster et al., 1999). Despite the increase in high school mathematics credits since the mid-80s, college algebra, precalculus, and calculus are some of the most frequently failed or dropped courses in higher education while freshman-level mathematics courses dominate the top-ten list (Adelman, 2003, 2004). The mathematical underpreparedness of college bound students may be related to three factors: First, students are less driven to excel once they arrive in college as they learn to be personally and educationally independent (Hassel & Lourey, 2004). Second, student accountability in college coursework is mediocre (Zelkowski, 2012). Third, high school mathematics rigor (instructional intensity) has declined due to evidence that high school grade point averages are inflated (Zelkowski, 2011; ACT, Inc., 2005; Conley, 2000). This study focused on detecting the likely contributors to poor mathematics performance on the advanced placement (AP) calculus AB exam at a private school in the southeastern U.S.

## Calculus Background

Many high schools offer calculus at two different levels, AP and regular. These two courses are differentiated by the rigor, pace of instruction, and expectations. Typically, a regular calculus class introduces basic calculus concepts, proceeds slowly, and does not focus deeply on the advanced problem solving required for AP exam preparation. An AP course moves more rapidly, requires students to be diligent at studying outside of school daily, and challenges students at higher cognitive levels regarding calculus concepts and problem solving. However, some high schools offer only AP calculus taught at a level consistent with regular calculus courses. The AP label merely is there to attract students, make parents happy, and help bolster student transcripts (Sadler, 2010). As a former AP calculus teacher and college mathematics instructor and current high school mathematics teacher educator, I can attest to these conditions in the mathematics classroom. My experiences as a teacher, professor, and researcher nicely position me with the skills and knowledge to conduct this descriptive case study as an independent, no stakes evaluator, for a private school.

While mathematics course-taking in high school has been rising significantly for 25 years or so (Shettle et al., 2007), high school mathematics achievement, college-readiness, and college success in mathematics have not kept pace (ACT, Inc., 2005; Horn, 2006; Knapp et al., 2010; Rampey et al., 2009). This mathematical lag poses a problem for both high school mathematics programs and mathematics departments in higher education around the U.S.

## *Purpose of the Study*

A private K-12 school in Alabama sought a researcher to study its declining AP calculus program. This school, I will call it Rolling Hills Academy (RHA), sought an external, neutral, and independent researcher, to study the program and make recommendations for turning around AP calculus exam results. The purpose of this research was to explore factors (e.g. transcripts, classroom practices, achievement) related to academic environment of the AP calculus program at RHA. According to RHA's high school principal, prior to 2004, the program produced average AP calculus scores relative to surrounding public schools. Since 2004, the AP calculus exam scores at RHA have steadily declined and remained consistently low. The goals for this study were to pinpoint with empirical data the factors that are likely contributing to declining AP calculus exam scores since 2004. The research questions guiding the collection of data were: (a) What academic issues at Rolling Hills Academy are influencing the AP calculus program? (b) Why has the AP calculus program declined since 2004? (c) How are pedagogical practices influencing or contributing to the declined achievement? (d) How can change improve achievement?

## *Method*

This study employed a non-experimental descriptive case study research design to strengthen the opportunity to triangulate findings regarding the decline of the AP calculus program at Rolling Hills Academy. Yin (2009) indicated the best approach, for a single unit of analysis to address how and why questions, is the case study. Further, an archival analysis suits analyzing the historical path since 2004 using transcripts. Cresswell (2003) indicated a rich qualitative case study is conducive for an interpretative study to find themes, personally and theoretically, allowing for inductive and deductive reasoning to answer research questions. This method of study created an environment where the researcher-self and personal-self were inseparable. Mertens (2003) reported the potential bias of the interpretive findings, but that honesty, openness, and personal reflection can eliminate the potential biases. As the researcher without financial or personal ties to this private school, after receiving permission from Rolling Hills Academy's administration and the researchers' institutional review board, full access was granted to begin the study in January of 2009.

## *The Researcher Disclosures*

During the time of data collection, I was a first- and second-year assistant professor of secondary mathematics education. Final analysis of the two-years of study occurred during my third-year faculty member. Prior to the start of my research career, I was a successful AP calculus high school teacher and college mathematics instructor receiving excellent AP exam scores and teacher ratings. I brought 10+ years of calculus teaching experience to this study. My expertise in the teaching of advanced mathematics presented an opportunity for a well-versed former teacher and knowledge-

able, budding researcher to examine classroom instruction and mathematics achievement. The researcher was not compensated for this research by Rolling Hills Academy but was provided a researchable opportunity as a junior faculty member with full access to the school without impediment as he began his research career.

## *Participants*

The participants of this study included teachers and administrators, while students were only observed during class instruction. AP calculus exam scores from May 2004 through Math 2010 were examined. Three mathematics classroom teachers and three administrators participated at different times of the study. Students were not part of the study as they were not the unit of analysis, though student transcripts who took the AP calculus exam were coded and analyzed to understand the unit of analysis the AP calculus program.

## *Data Collection*

Data were collected through four sources. First, semi-structured interviews took place with the three mathematics teachers (in year-one, two teachers and in year-two, an additional teacher came on board) teaching the courses of algebra-1 through calculus. Second, 44 unscheduled classroom observations (about 50 hours) of instruction occurred periodically over the course of two years. The unscheduled observations allowed me to see typical everyday class routines rather than preplanned visits that may have prompted teachers to change their regular classroom routine. Third, informal interviews with the high school (grades 9-12) principal and the K-12 headmaster provided insight to the day-to-day operations of the school and their perspectives of the AP calculus program. Last, student transcripts and AP exam results summary pages were included in the archival analyses. Students who completed the AP calculus exam in May 2004 through May of 2010 had their high school transcripts coded, variables created, grade point averages (GPA) calculated while identifying course taking patterns (see appendix A for variables and coding). Students at RHA who did not attempt the AP calculus exam did not have transcripts included in the documental analyses because the AP calculus program was the unit of analysis. Multiple forms of data collection strengthen the study's findings and provide a rich data set to make recommendations with goals of long-term improvement.

## *Procedures*

Because Rolling Hills Academy is such a small private school with AP calculus enrollments ranging from three to 14 students per year since the 2003-04 school year, group differences were not expected to be statistically detectable so quantitative analyses were not practical. Therefore, descriptive statistics and a simple linear regression model served as the means for determining overall performance of students completing AP calculus at RHA. All interview or focus

group discussions were audio recorded as a means to clarify and align with the notes taken during such meetings. In the spring of 2009, I began data collection. First, semi-structured interviews took place with the AP calculus and precalculus teacher (see Appendix B for protocol). Both teachers also taught algebra-2 and geometry. Following the initial teacher interviews, I proceeded to make unannounced observations of classroom instruction in precalculus and calculus. Following the first half of classroom observations, I held a focus group discussion with both teachers. The focus group discussion was to discuss the daily routines of classroom instruction, permit me to ask probing questions, and allow the teachers to reflect on the observations of instruction. During the spring interview and observation period, I obtained the transcripts of all students who completed the AP calculus AB exam through the records office at RHA for AP test-takers in 2004 through 2008 and the expected AP test-takers for May 2009. At the conclusion of the 2008-09 school year, I met with the 9-12 principal and K-12 headmaster. A debrief of year-one findings was discussed extensively, suggestions for improvement were made, and changes were implemented for the start of the 2009-10 school year. I suggested an additional year of study to follow closely to examine change and effectiveness based on the recommendations. As the study moved forward in year-two, I obtained the transcripts from the students who were expected to complete the May 2010 AP exam.

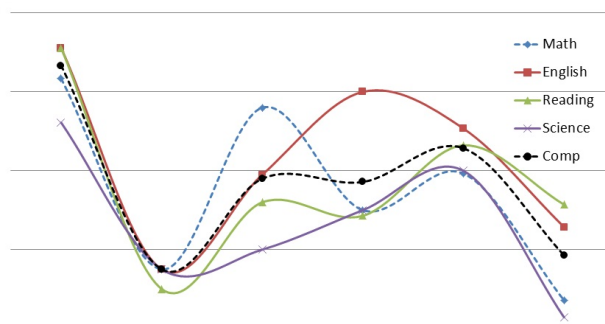
## Analysis

### Year-One Archival Analysis

During the spring of 2009, student transcripts of AP calculus test-takers were inspected, coded, and analyzed (see appendix A for coding). Included in the creation of the data spreadsheet were the AP exam scores along with ACT/SAT scores. Table 1 depicts the transcript summary of AP test-takers from the May 2004 exam through May 2009. The AP calculus exam results were not available at the onset of the study for the May 2009 results, and neither were complete transcripts for grade 12. I added to the spreadsheet the nine students who took the AP exam in May 2009 after RHA received the 2009 AP calculus results. For all the AP test-takers since 2004, Figure 1 presents a graphic to depict the mean ACT trends across all test content areas while Figure 2 depicts individual ACTm scores with the regression line.

ACTm scores were found to be highly correlated ( $r = .509$ ) to AP calculus exam scores. In Figure 2, the regression line ( $\text{ACT-math} = -0.98673(\text{year}) + 2006.1$ ) represents students who completed the AP calculus exam and have seen, on average, their ACT math scores dropping nearly one full point per academic year. Student GPAs in mathematics courses have tended to be dropping over time in each of the mathematics courses except algebra-1, but the grades in coursework were dropping at less than the ACTm result-san indication of some grade inflation. However, many students completed algebra-1 prior to grade 9 and some students grades were not available. A closer examination revealed

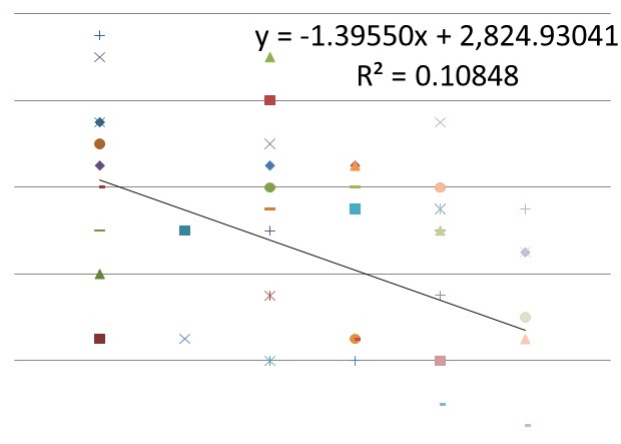
Figure 1. ACT test mean data 2004-2009



Notes: ACT section and composite scores 2004 to 2009 AP calculus test-takers. In 2005, only three students took the AP exam which skews the data.

a much different interpretation. When examining students un-weighted GPAs individually, transcript analysis indicated only five of the 53 students (2004-09) who took the AP exam had math GPAs at RHA under 3.0, all scoring a 1 on the AP exam. In fact, 16 of 53 students had math GPAs over 4.0 and only six of these 16 students earned a 3 or better on the AP exam. Fifteen students had GPAs between 3.0 and 3.5 with 14 students scoring a 1 on the AP exam and one student scoring a 2. The remaining 17 students with a math GPA between 3.5 and 4.0, 13 scored a 1 on the exam, three scored a 2, and one scored a 3.

Figure 2. ACT-math trends for AP test-takers

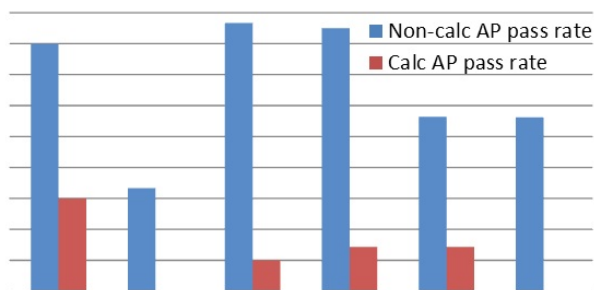


Notes: Some ACT-math scores are duplicated indicating fewer dots per year than number of AP test-takers in each year. Four students did not complete the ACT in years: 2004 (1), 2005 (1), 2009 (2).

After discovering this, I further analyzed the transcripts. As the researcher, I wondered if other AP subjects were hav-

ing the same issues at RHA by the AP calculus students or was it just AP calculus? I then coded the three variables (1) AP courses completed, (2) AP exams taken, and (3) AP exams passed. Figure 3 presents the pass rates AP exams from 2004-09 at RHA for AP calculus test-takers only. This data shows with the exception of 2005, students who took the AP calculus exam succeeded at a much higher rate on other AP subject exams. However, there was a drop in pass rates on non-calculus AP exams in 2008 and 2009. Overall student ability appeared to not be hindering AP exam results, as students were relatively successful each year on other AP exams.

Figure 3. AP calculus pass rates v. Non-calculus AP pass rates for AP calculus test-takers only



Notes: Total AP exams taken each year (non-calculus, calculus). 2004(35,10); 2005(3,3); 2006(30,10); 2007(20,7); 2008(39,14); 2009(16,9).

### Year-One Interview/Observation Analysis

Before classroom observations, interviews with the two mathematics teachers (Mr. Ward and Mrs. Wallace) took place. During these interviews, I asked basic questions about their general impressions of the mathematics achievement of their students (see Appendix B for semi-structured interview protocol). During the audio-recorded interviews, extensive notes were taken and follow-up clarification questions were asked to pinpoint exactly what the two teachers meant. After the interviews concluded, the notes were reviewed, confirmed with the audio recordings, and coded into five categories. These five categories were: (1) Student accountability, (2) Teacher accountability, (3) Pedagogy, (4) Technology, and (5) Assessment.

After coding the teacher responses, the majority (60%) of comments during the interviews with the teachers resulted in the two teachers placing much of the blame for poor mathematics achievement on the students work ethic and prior abilities (Student accountability). Both teachers gave descriptions of their instruction being thorough (Pedagogy, 15%) and well planned-out (Teacher accountability, 15%). Only 10% of the comments pertained to the use of technology and assessments in the classroom (5% each). A week after coding and analyzing the interview data, I began two months

of observing the classroom, on average 1.5 times per week per teacher. A total of 12 observations took place in Mr. Wards and Mrs. Wallaces classrooms for a total of 24 observations. Each observation was randomly observed (teachers did not know I was coming) to see the typical classroom day. I developed a rubric to rate classroom instruction pedagogically (see Appendix), using the characteristics of teacher-centered instruction and student-centered instruction (see(Cobb, 1988; Grouws, 1992; National Research Council, 2000; Piaget, 1969; Simon, 1995).

The precalculus teachers (Mr. Ward) mean rating on the five-point scale was 1.167 for 12 observations of the precalculus class. All lessons were almost exclusively teacher-centered direct lecture during which students took notes. The teacher regularly worked a few examples, and then, on most days, the students started their homework before class ended. Two lessons for Mr. Wards precalculus course were rated as a two because the teacher asked two students to come to the board and present their solutions to problems before moving to the next example.

Rolling Hills Academy is a laptop school, requiring each student brings a laptop to class daily. Four of the 12 students in the precalculus course regularly browsed the internet (e.g. facebook, espn) and checked email. Mr. Ward rarely took the time to question or engage students so they would be active in learning the course material. Additionally, Mr. Ward posted all of the class notes online each evening, so students did not take notes completely during class since it could be downloaded from the internet. It appeared to me that students were bored or uninterested due to the lack of questioning and discussions during class, thereby resulting in the students browsing online for much of the class. Exams, homework, and quizzes were classified as only assessing students at the lowest cognitive levels memorization and procedures without connections (see (Stein et al., 2009)). More than 90

The AP calculus teacher (Mrs. Wallace) was observed 12 times (10 calculus and 2 geometry). Some of these observations were the same day as the precalculus teacher, Mr. Ward, and some were on different days. Mrs. Wallace had been with Rolling Hills Academy for well over a decade before taking over the AP calculus class in 2005. Mrs. Wallace had attended three summer AP calculus College Board professional development workshops prior to this study beginning. Mrs. Wallace commented during the initial interview about Calculus in Motion (see Weeks website <http://www.calculusinmotion.com/>) and some other tools from the workshops. However, during the 10 calculus observations, I never observed Mrs. Wallace use any materials mentioned during the initial interview. Mrs. Wallace did use the overhead projector TI-Viewscreen™ for the TI-83 graphing calculator. On all occasions with the exception of once, this technology tool was used solely for computing a numerical derivative or integral. The lone exception was when Mrs. Wallace used the technology as an inquiry tool to work through a College Board released 2005 AP calculus free-response problem. However, all of the difficult thinking was done by Mrs. Wallace and no questioning took place in the classroom students just took notes. All 12 of the

lessons observed were rated 1 on the five-point scale previously mentioned. When students were given challenging problems to solve in class or for homework, struggling students had learned to just go up and ask the teacher for guidance. Mrs. Wallace provided many of the first steps (the difficult thinking) to get started on the problem a common example of how cognitive effort can be reduced significantly in mathematics classrooms. Of all of the observations in calculus and geometry, 95

### *Recommendations Made after Year-One*

Five major findings overlapped between both Mrs. Wallace and Mr. Wards interviews and classroom observations prompting these recommendations. First, students need to become more engaged in using technology as a learning tool for mathematical inquiry rather than solely as a computational tool since AP exams are written with the expectation students have a handheld graphing calculator for the portion of the exam requiring one. For example, students rarely used the calculator to conjecture or discover the connections between different representations of functions or with respect to advanced problem solving. Second, homework changes need to occur. One or two advanced problems are worth their weight in gold compared to 20 skill problems with no context. There needs to be skill problems assigned regularly, but the problems need to include graphical, numerical, and written explanations with respect to functions, not entirely algebraic representations. Almost all (90

### *Year-One Changes*

After reviewing the research findings with the 9-12 principal, two major changes prompted a second year of data collection. First, the precalculus and algebra-2 teacher, Mr. Ward, did not return to Rolling Hills Academy. Mr. Ward had been at the school for less than three years. Second, the AP calculus teacher was moved to teaching algebra-2, geometry, and some algebra-1. A new teacher, Mr. Miller, replaced Mr. Ward on the faculty and had previous calculus teaching experience at another private school in the state. Mr. Miller took over teaching precalculus, AP calculus, and some algebra-1. Before the start of the 2009-10 school year, I met with Mr. Miller to discuss the research findings, recommendations for change, and provided a small amount of professional development with regard to using technology in the teaching of high school mathematics, including calculus.

### *Year-Two Overview*

During the 2009-10 school year, 10 observations took place in both precalculus and AP calculus for a total of 20 observations of Mr. Millers upper level mathematics classes. Four general findings emerged after analyzing the observation notes and comparing the notes to the previous years observation notes. First, both courses had increased in rigor and expectations of students in the courses. Most importantly, the precalculus course made improvements from the 2008-09 year. Students in the 2009-10 precalculus course would

be much more prepared for AP calculus in 2010-11. Second, there was a much improved atmosphere of learning in both courses, as it was observed that students and teacher were more active in exchanging mathematical discourse. However, it was obvious that the 2009-10 calculus students were still somewhat behind from the 2008-09 precalculus class. Many students lacked prerequisite knowledge for AP calculus though students were still challenged during class in a positive manner. Mr. Miller was observed using various pedagogical practices including traditional teacher lecture, students working in groups, and students presenting problems on the board in teams. There was much more proactive learning by the students observed in year-two than year-one in both precalculus and calculus. Third, a strong improvement had been made on the use of technology at higher cognitive levels than previously. In the initial year of study, only basic, low level cognitive skills (computation, simple graphing) were used in parallel with technology. In year-two, a number of more sophisticated questions and concept examinations occurred by using the AP professional development workshop materials. Mr. Miller used AP released exam items for parts of the summative assessments and solved problems in class with and without technology. Last, my general findings were that change was occurring but that at least another year or two would be needed to see AP exam scores increase. The expectations on students throughout the grades 9-12 mathematics curriculum still needed to be increased. Vertical alignment still needed work. It was anticipated that the 2009-10 calculus test-takers would not do well on the AP exam because their 2008-09 precalculus course was not rigorous. The 2010-11 test-takers would be better prepared for the AP calculus exam due to the improved 2009-10 precalculus improvements.

### *2010 AP Test-takers Archival Data.*

The trend continued for the eight test-takers, with six students scoring 1 on the AP calculus exam. One student scored a 2 and the final student scored a 5. The overall mean was 1.625, higher than any other year since 2004. However, much of this difference can be attributed to the lone student scoring a five, which had only happened but twice since 2004 (once in 2006, once in 2008). Moreover, the increased course rigor for this group of test-takers resulted in improved ACT math scores, breaking the trend of a steady decline since 2004. This group of students had a mean ACT math score from their junior year of 24.4 the regression model from 2004-2009 predicted 22.8. Seven of the eight students took the ACT in October of their senior year. The two months of precalculus review by Mr. Miller paid off. The mean ACT math score rose to 27.1, nearly three full points. The resulting AP effect was less time to cover calculus content, but students were so far behind in precalculus knowledge from the prior year, this investment was worth it based on the ACT data. The regression lines slope decreased from 0.9867 (2004-09 test-takers) to -0.5321 when the 2010 test-takers data is included and reduces the R2 from 16.1

All of these findings point towards expecting a much bet-

ter result on the AP exam in the spring of 2011 because those students will have experienced a full year of rigor in precalculus with a the new teacher. Additionally, the 2011 test-takers will not need to spend two months reviewing precalculus material and can focus more time on important AP calculus material earlier at the start of the 2010-11 school year.

## Discussion

Over the course of two school years, much was discovered while trying to answer the four research questions guiding this research. First, the most detectable academic issues at Rolling Hills Academy were the linear decrease of ACT mathematics scores from 2004-09. This trend strongly indicated that precalculus mathematics courses were losing rigor and that grade inflation was a strong possibility. Grade inflation was somewhat apparent by seeing little overall change in mathematics GPAs at the same time ACT-math scores were dropping. The Pearson-correlation coefficient between mathematics GPA and ACT-math scores in 2004 was 0.74, decreasing to 0.63 in 2009. The drop in correlation was interpreted as an indication GPAs are not coming down as much as the ACT-math scores were dropping annually. Qualitative findings related to research question number were consistent. Students were being assessed primarily only at the lowest cognitive levels. Students were not being challenged and prepared for advanced assessments like the AP calculus exam. Teachers in year-one were not delivering engaging lessons in precalculus and calculus classes focusing much of the thinking towards the teacher rather than students. Each issue discovered, with regards to research question one, was targeted in the recommendations previously mentioned.

The second research question was addressed only through classroom observations and teacher interviews. The pedagogical practices in precalculus and calculus classes, during year-one of this study, were well defined. The teacher was the center of instruction nearly 100% of the time. Students were rarely actively engaged in their own learning during class other than taking notes and solving homework problems. Direct lecture has a place in teaching and learning. However, direct lecture rarely can reach 100% of the students without some variation of instructional strategies that is supported by research in the past 20 years indicating students learn and retain information better when they are actively engaged in constructing their own learning (Hiebert, 2003; Kilpatrick et al., 2001). More specifically, mathematical procedures are often easily and quickly forgotten, but when focusing on concepts through reasoning and sense making, students have more in their toolbox to be problem solvers (NCTM, 2009). Year-two pedagogical practices in precalculus and calculus were much more in line with research supported best practices. Plus, students seemed to enjoy and participate in class more than in year-one. I thought students were not participants.

The third research question dealt specifically with changes that needed to occur first. Five recommendations were made after the findings were determined for the first two research questions. Of the five recommendations, Rolling

Hills Academy decided to tackle the poor AP performances by making teacher changes. During year-two, three of the five recommendations were addressed and change was evident. First, technology was being used much more as an inquiry tool, rather than computational tool. There was room for improvement, but a shift in technology pedagogy use was apparent. Second, fewer overall homework problems were being assigned in addition to one or two more advanced problems, though this was not regularly observed (only about 25

The final research question examined whether or not changes implemented after year-one yielded positive results. The linear decrease in GPA-ACTm correlation values changed and reversed direction in 2010. The Pearson correlation coefficient was 0.67 in 2010 as opposed to a steady drop from 2004-09. This indicates the correlation between GPA-ACTm scores increased closer to perfect correlation (0.62 to 0.67). Many of the issues found in year-one were greatly improved in year-two, as evidenced by ACTm score improvements and student engagement. During classroom observations, more students took notes, asked thoughtful questions, and seemed eager to participate. Further, students were completing homework at higher rates than year-one. The large increase in ACTm scores eliminated six years of decline. These positive findings indicate improvement. Yet, the AP scores did not improve indicating more work is needed.

## Limitations

This study focused on one small private K-12 schools struggling AP calculus program. The findings are not generalizable to larger populations, though they do suggest areas other struggling AP calculus programs might examine with respect to their own achievement data and classroom practice. The findings in this study are limited to one school and the AP calculus test-takers at Rolling Hills Academy from 2004-10. I was immersed in the collection of all data and interpretation of the data, though the researcher had no ties to the school or program of study with any compensation. As the researcher, my compensation was full access to the school and data as needed to do the research. In trade, my service time for research and professional development solidified the professional relationship between school and researcher. Transcript data was coded by a graduate student and the data is limited to the accuracy of data entry. Data was coded and rechecked by the graduate student. It is expected to be at least 98

An additional limitation for applying this research method to other struggling programs would be the difficulties with making such major teacher changes in public schools. Such changes may be resisted by tenured public school teachers and their teacher union in smaller schools comparable to Rolling Hills Academy. Larger schools would have enough teaching resources to move faculty within schools or district systems if such changes would be needed.

A final limitation in the interpretation is that one class of students may have significantly been more proactive in general in their studies. Year-two students may have felt more obligated to be proactive with the school changing teachers



or knowing a researcher was evaluating the changes made from year-one to year-two. However, the large number of observations and large increase in ACTm scores makes this limitation unlikely but still possible.

### *Recommendations for Future Research*

The findings in this study indicate Rolling Hills Academy was serious about changing their struggling AP calculus program. Moreover, change was evident in year-two. While future projections cannot be made accurately, they can be predicted with some educated forecasting. It is expected the May 2011 test-takers will do somewhat better on the AP calculus exam and fewer 1 scores on the exam should begin to appear. However, until major changes in rigor and expectations occur in all grades 8-11 prior to calculus in grade 12, consistent passing scores of 3 or better are not expected to begin with regularity. The new AP calculus teacher Mr. Miller went through one summer College Board AP workshop and implemented a number of pieces into his practice. It is expected this will only grow as the teacher participates in future summer AP calculus workshops. Mr. Miller has expressed interest in being an AP exam reader/scorer when exams are scored nationally. Future program evaluation is expected to take place in two years after Mr. Miller has been the precalculus and calculus teacher for three full years.

Because many public schools have struggling AP calculus programs, I believe there are many lessons that could be learned by a similar study across multiple schools. A comparison study of an exemplary and struggling public school AP calculus programs with similar confounding factors and school characteristics would be beneficial to the research community and schools aiming to improve their AP calculus program. As the researcher actively in public schools and a private school, I wondered how much random access a researcher would have to showing up and observing a public school classroom teacher without notice? I suspect this would be difficult for a teacher and school administration to agree to in a public school. Hence, this is a limitation of replication in a public school setting perhaps. My current experiences have been teachers who know you are coming prepare differently for instruction knowing they are being observed by an outsider working with the school system.

### *Summary*

On the school level, it is recommended AP calculus programs examine more than just test scores and student achievement. Examining teaching practices, student engagement, technology integration, and cognitive levels of assessment items are important to determining areas of weakness in AP calculus programs, as well as completing random classroom observations of instruction. Declining AP exam scores may not be linked to just calculus classrooms either. Looking at student GPAs and college entrance test scores may point more towards the precalculus classes all the way down the mathematics ladder to grade eight mathematics. The importance of vertically aligning the curriculum and teacher expectations are paramount. It will be interesting to learn whether

these discovered changes result in long-term improvements in AP calculus scores at Rolling Hills Academy.

### References

- ACT, Inc. (2005). *Courses count: Preparing students for postsecondary success.* author, Iowa city, IA. Retrieved from <http://www.act.org/research/policymakers/pdf/CoursesCount.pdf>.
- Adelman, C. (1999). *Answers in the toolbox: Academic intensity, attendance patterns, and bachelor's degree attainment.* U.S. Department of Education, Institute of Educational Sciences, Washington, DC. Retrieved from <http://www.eric.ed.gov/PDFS/ED431363.pdf>.
- Adelman, C. (2003). *Postsecondary attainment, attendance, curriculum, and performance: Selected results from the NELS:88/2000 postsecondary transcript study (PETS), 2000.* U.S. Department of Education, Institute of Educational Sciences, Washington, DC. Retrieved from <http://www.eric.ed.gov/PDFS/ED480959.pdf>.
- Adelman, C. (2004). *Principal indicators of student academic histories in postsecondary education, 1972-2000.* U.S. Department of Education, Institute of Educational Sciences, Washington, DC. Retrieved from <http://www.eric.ed.gov/PDFS/ED483154.pdf>.
- Adelman, C. (2006). *The toolbox revisited: Paths to degree completion from high school through college.* U.S. Department of Education, Institute of Educational Sciences, Washington, DC. Retrieved from <http://www.eric.ed.gov/PDFS/ED490195.pdf>.
- Anthony, G. (2000). Factors influencing first-year students' success in mathematics. *International Journal of Mathematical Education in Science & Technology*, 31(1):3-14. doi:10.1080/002073900287336.
- Aycaster, P. W. (2001). Factors impacting success in community college developmental mathematics courses and subsequent courses. *Community College Journal of Research & Practice*, 25(5/6):403-416. doi:10.1080/106689201750192256.
- Cerrito, P. B. and Levi, I. (1999). An investigation of student habits in mathematics courses. *College Student Journal*, 33(4):584.
- Cobb, P. (1988). The tension between theories of learning and instruction in mathematics education. *Educational Psychologist*, 23(2):87-103.
- Conley, D. T. (2000). Who is proficient: The relationship between proficiency scores and grades. In *Proceedings of the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 24-28, 2000)*. <http://www.eric.ed.gov/PDFS/ED445025.pdf>.

- Cresswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approach*. Sage Publications, Inc., Thousand Oaks, CA, 2nd edition.
- Duncan, H. and Dick, T. (2000). Collaborative workshops and student academic performance in introductory college mathematics courses: A study of a treisman model math excel program. *School Science & Mathematics*, 100(7):365–373. doi:10.1111/j.1949-8594.2000.tb18178.x.
- Duranczyk, I. M. and Higbee, J. L. (2006). Developmental mathematics in 4-year institutions: Denying access. *Journal of Developmental Education*, 30(1):22–31.
- Grouws, D. A., editor (1992). *Handbook of research on mathematics teaching and learning: A project of the national council of teachers of mathematics*. National Council of Teachers of Mathematics, Reston, VA.
- Gupta, S., Harris, D. E., Carrier, N., and Caron, P. (2006). Predictors of student success in entry-level undergraduate mathematics courses. *College Student Journal*, 40(1):97–108.
- Hiebert, J. (2003). What research says about the NCTM standards. In Kilpatrick, J., Martin, W. G., and Shifter, D., editors, *A research companion to principles and standards for school mathematics*, pages 5–23. National Council of Teachers of Mathematics, Reston, VA.
- Horn, L. (2006). *Placing college graduation rates in context: How 4-year college graduation rates vary with selectivity and the size of low-income enrollment (NCES 2007-161)*. U.S. Department of Education, National Center for Education Statistics, Washington, D.C. Retrieved from <http://www.eric.ed.gov/PDFS/ED494020.pdf>.
- Ironsmith, M., Marva, J., Harju, B., and Eppler, M. (2003). Motivation and performance in college students enrolled in self-paced versus lecture-format remedial mathematics courses. *Journal of Instructional Psychology*, 30(4):276–284.
- Kilpatrick, J., Swafford, J., and Findell, B., editors (2001). *Adding it up: Helping children learn mathematics*. National Academy Press, Washington, DC.
- Knapp, L. G., Kelly-Reid, J. E., and Ginder, S. A. (2010). *Enrollment in postsecondary institutions, fall 2008; graduate rates, 2002 & 2005 cohorts; and financial statistics, fiscal year 2008 (NCES 2010-152)*. U.S. Department of Education, National Center for Education Statistics, Washington, D.C. Retrieved from <http://nces.ed.gov/pubs2010/2010152rev.pdf>.
- Mertens, D. M. (2003). Mixed methods and the politics of human research: The transformative-emancipatory perspective. In Tashakkori, A. and Teddlie, C., editors, *Handbook of mixed methods in the social and behavioral sciences*. Sage Publications, Inc., Thousand Oaks, CA.
- National Center for Education Statistics (NCES) (2010). *The nations report card: Grade 12 reading and mathematics 2009 national and pilot state results (NCES 2011455)*. U.S. Department of Education, Washington, D.C. Retrieved from <http://nces.ed.gov/nationsreportcard/pdf/main2009/2011455.pdf>.
- National Council of Teachers of Mathematics (NCTM) (2009). *Focus in high school mathematics: Reasoning and sense making*. Author, Reston, VA.
- National Research Council (2000). *How people learn (expanded edition)*. National Academy, Washington, DC.
- Penny, M. D. and White, W. G. (1998). Developmental mathematics students' performance: Impact of faculty and student characteristics. *Journal of Developmental Education*, 22(2):2–9.
- Piaget, J. (1969). *The mechanisms of perception*. Basic Books, New York.
- Rampey, B. D., Dion, G. S., and Donahue, P. L. (2009). *NAEP 2008 trends in academic progress (NCES 2009-479)*. U.S. Department of Education, National Center for Education Statistics, Washington, D.C. Retrieved from <http://nces.ed.gov/nationsreportcard/pdf/main2008/2009479.pdf>.
- Royster, D. C., Harris, M. K., and Schoeps, N. (1999). Dispositions of college mathematics students. *International Journal of Mathematical Education in Science & Technology*, 30(3):317–333. doi:10.1080/002073999287851.
- Sadler, P. M. (2010). How are AP courses different? In Sadler, P. M., Sonnert, G., Tai, R. H., and Klopfenstein, K., editors, *A critical examination of the advanced placement program*, pages 51–62. Harvard Education Press, Cambridge, MA.
- Shettle, C., Roey, S., Mordica, J., Perkins, R., Nord, C., Teodorovic, J., Brown, J., Lyons, M., Averett, C., and Kastberg, D. (2007). *The nations report card: Americas high school graduates (NCES 2007-467)*. U.S. Department of Education, National Center for Education Statistics, Washington, DC. Retrieved from <http://nces.ed.gov/nationsreportcard/pdf/studies/2007467.pdf>.
- Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*, 26:114145. doi:10.2307/749205.
- Stein, M. K., Smith, M. S., Henningsen, M. A., and Silver, E. A. (2009). *Implementing standards-based mathematics instruction: A casebook for professional development*. Teachers College Press, New York, 2nd edition.
- Yin, R. K. (2009). *Case study research: Design and methods*. Sage Publications, Inc., Thousand Oaks, CA, 4th edition.



Zelkowski, J. (2011). Defining the intensity of high school mathematics: Distinguishing the difference between college-ready and college-eligible students. *American Secondary Education*, 39(2):27–49.

Zelkowski, J. (2012). Student accountability, achievement, and instructor variability in a college calculus course. preprint.

## Appendices

## Tables

Table 1  
*Descriptive Data for 2004-09 AP Calculus Test-takers*

	Year	2004	2005	2006	2007	2008	2009	Means
	n	10	3	10	7	14	9	8.8
Grade	Alg-1	3.89	N/A	3.50	3.42	3.00	4.00	3.55
	Geom	3.94	N/A	3.94	3.95	3.63	3.52	3.76
Point	Alg-2	4.02	N/A	3.98	3.81	3.74	3.25	3.76
	Precalc	3.95	N/A	3.87	3.83	3.51	3.50	3.71
Averages	AP calc	3.77	3.39	3.47	3.65	3.42	3.22	3.49
	Overall	3.94	3.17	3.81	3.77	3.54	3.41	3.65
ACT	Math	28.33	23.50	27.60	25.00	25.93	22.71	26.02
	English	29.11	23.50	25.90	28.00	27.07	24.57	26.84
	Reading	29.11	23.00	25.20	24.86	26.64	25.14	26.18
	Science	27.22	23.50	24.00	25.00	26.00	22.29	25.04
	Comp	28.67	23.50	25.80	25.71	26.57	23.86	26.16
	AP mean	2.10	1.00	1.50	1.43	1.57	1.11	1.53

ACT scores only reported, less than 20% of students took SAT which is common in the southeastern state. In 2005, the three AP test-takers did not complete precalculus mathematics courses at Rolling Hills Academy.

Table 2  
*Rubric for Rating Classroom Pedagogical Instruction*

1	2	3	4	5
Teacher Centered		Balanced		Student Centered
<ul style="list-style-type: none"> <li>• Direct Lecture</li> <li>• Students take notes</li> <li>• Teacher works repeated examples</li> <li>• Teacher asks questions with specific right answers</li> <li>• Teacher does much of the critical thinking in problems solving</li> <li>• Behaviorist theories of learning</li> </ul>		<ul style="list-style-type: none"> <li>• Shows signs of categories 1 and 5 equally</li> <li>• May also include students presenting collaboratively or individually</li> <li>• Manipulatives, including technology, are used in conjunction with concept attainment</li> </ul>		<ul style="list-style-type: none"> <li>• Teacher poses problem to class, allowing students to investigate</li> <li>• Inquiry lesson design</li> <li>• Students investigate concepts, possibly in groups</li> <li>• Teacher asks scaffolded questions to lead students</li> <li>• Students often required to think on their own</li> <li>• Constructivist theories of learning</li> </ul>

### *Coding of transcript data*

Grades were coded using a 0 to 4.333 GPA model where + and grades added/subtracted 0.333 from the letter grade. For example, 2.666 would represent a B-.

All of these listed variables were coded from the 53 AP test-takers high school transcripts from 2004 to 2009. Eight additional test-takers were added in year 2, 2010 test-takers.

- Student number
- Sex
- Graduation year
- Order of taking mathematics courses (Alg-1, Geom, Alg-2, OR Alg-1, Alg-2, Geom, )
- Algebra-1 taken in grade 8 or earlier
- Mathematics courses taken continuously (no semester or year without math)
- AP credits enrolled/completed
- AP exams taken
- AP exams passed
- Grades in Algebra-1, Geometry, Algebra-2, Trig/Precalculus, Calculus
- Overall high school GPA (with and without math GPA)
- ACT-math
- ACT-English
- ACT-reading
- ACT-science
- ACT-composite
- SAT-math
- SAT-verbal
- SAT-composite
- Calculus AP AB exam score

### *Interview question list for teachers*

1. What mathematics classes are you teaching? How long?
2. How would you describe your teaching style?
3. How would you describe the classroom setting during most days?
4. What are your expectations of students inside and outside the classroom? Homework? Etc.
5. Why do you believe that students are not doing well on the AP calculus exam?
6. How do you use technology in the classroom? The students?
7. When you create a summative assessment, describe your thoughts and process for doing so?
8. Have you participated in any AP professional development? If so, when? How has the PD influenced your teaching since attending? Describe changes or innovations since.

Topics of discussion possible if needed to deepen discussions

- Pedagogical practices
- Technologies
- Beliefs, values, expectations
- Student motivation, teacher motivation
- Rigor
- Difficulties
- Administration support