The Effect of High School Calculator Usage on First-Year College Calculus Grades

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Abstract

This paper investigates the impact of high school calculator usage on first-year college calculus grades, a relationship for which a dearth of material exists. Using the national FICSMath survey of students in college calculus, we perform a factor analysis on the calculator variables of interest to construct 2 composites signifying latent characteristics of calculator use in high school classrooms. A multiple linear regression analysis is carried out, controlling for standard confounding variables, such as race, gender, socioeconomics, etc. Lastly, interaction effects are examined, and we identify a statistically significant interaction between our two composites: 'zealotry' and 'restricted'. We find that the more extensively students had used calculators in high school the lower their course grade in first-year college calculus. A high degree of restrictedness helps mitigate this effect.

I INTRODUCTION

What best prepares a student for success in college calculus? Many have pondered how best to instruct students during high school and what particular methods work best for a fundamental understanding of the material. Specifically, "the increased use of technology and the changing demands of the workplace have changed the nature of mathematics instruction since the last few years" (Tajuddin et al. 2009).

Since the early 1990s, these so-called 'Math Wars' have unnerved many mathematics educators across the country. The Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics, 1989) has advocated moving secondary school calculus to a more conceptual, applications-oriented, and technology intensive program. It involves a shift from a curriculum dominated by memorization of isolated facts and procedures to one that emphasizes conceptual understanding (Tajuddin et al. 2009). Some educators argue that the ever-growing popularity of technology is, in fact, advantageous to the mathematical growth of students. Estes et al. (1990) for example, found that the use of computers and hand-held graphing calculators in applied calculus positively impacts students conceptual achievement. According to the pro-calculator faction, the graphing calculator represents the direction of the pedagogical future (Kissane, 2000). In this view, the convenience of a graphing calculator, or a calculator in general, simply allows a more realistic mathematics lesson to take place. But others think exactly the opposite. In their view, calculator use detracts from acquiring essential mathematics skills.

Yet, critical issues have remained without thorough empirical examination. Is technology beneficial to the education of students, or is it detrimental? More specifically, does the use of technology prepare students for success in gateway mathematics/science courses in post-secondary education, or is the conservative faction of the 'Math Wars' correct? Are calculators useless and should their usage in the classroom be severely limited?

II LITERATURE REVIEW

Wilson & Naiman (2004) undertook a parallel study to ours with introductory calculus courses at Johns Hopkins University. Using students final course grades, SAT mathematics/verbal scores, categorical data on whether or not parents ever helped the students with mathematics coursework, and if calculator usage was emphasized or encouraged in K-12, they ran a regression analysis. They found a positive relationship between calculator usage and student performance (final grade) for the calculator coefficient in one case, the smallest calculus course (n=105), which had a p-value of .80. The largest (n=184) calculus course had a p-value of .50. The authors admit that the limited sample size is the cause of such results and suggest a re-administration of the survey and a clarification of the calculator question. Wilson & Naiman (2004) also did not control for SAT scores or respective schooling backgrounds, a control we will certainly implement. Still interesting was the positive result obtained, albeit non-rigorously.

In similar fashion, Tajuddin et al. 2009 found that integrating the use of graphing calculators into teaching and learning mathematics with secondary school students was more instructionally efficient (measured by the 3-D instructional efficiency) than the conventional (non-technological) teaching strategy. The study specifically measured the link between success on the Straight Lines Achievement Test and the TI-83 Plus in the teaching and learning of straight lines to 99 students from Malaysian secondary schools. A planned comparison test showed that the mean overall test performance of graphing calculator strategy group was significantly higher than those of the control group ($p<.05$), whose participants did not use the calculator. This study helped show that there is, at least in some settings, a benefit to using a graphing calculator as a supplement to in-class instruction.

Burrill & Breaux (2002) also found similar results - that access to and use of graphing calculators seems to increase course achievement. Using a 251-student sample from nine different school districts and three groups of teachers, organized by frequency of calculator usage, student achievement was measured via pretests and posttests. Student scores on the test were recorded before and after conducting the study. Students who owned calculators earned a significantly higher score on the posttest (57.8 percent) than those who did not (41.2 percent). This study, however, was simply a pilot study with sample sizes too small to justify any real conclusions. Nonetheless, it does suggest access and use of handheld graphing technology should routinely be part of the learning process if they are to be effective tools for learning.

The uncertainty on the effectiveness of technology on student achievement is the crux of the math wars, and our research seeks to interpret this inconsistency. Using a sufficiently large, comprehensive sample, we hope to identify a substantive relationship between calculator usage in secondary school and subsequent achievement in college calculus. We also hope to correct the pitfalls of the aforementioned studies by properly isolating all confounding elements of the study.

III WHY FOCUS ON COLLEGE CALCULUS?

This paper wishes to elucidate the relationship between students usage of calculators in high school and their subsequent success in their first-year college calculus course, should they continue with college-level mathematics. But why choose to hone in specifically on college calculus? College calculus is a crucial gateway course for all STEM disciplines (Sadler & Sonnert, 2013), as well as for pre-medical students. This course serves as the foundation and facilitator for student success in higher-level mathematics and science courses. In other words, succeeding in college calculus is an important stepping stone on the way to the many rewarding and well-paid careers in STEM fields and other associated areas (Mathematical Association of America, 2010).

The comparatively low number of STEM college graduates has raised concerns about the United States's ability to remain internationally competitive and its ability to foster future innovation (Wade, 2011). Only 37.1 percent of students who actively pursued a STEM degree actually earned a degree by 2001 in their intended field of study within 6 years of beginning the degree program in college. Of the remaining 62.9 percent of students who had originally started on a STEM degree path but did not earn a degree within 6 years, only 7.5 percent of those students remained enrolled in a STEM discipline, while roughly 27 percent had switched to non-STEM disciplines, and more than 28 percent had left college altogether (Chen and Weko, 2009).

A somehow deficient preparation of students for college calculus might be part of the problem, given the pivotal position of calculus for the study of STEM disciplines. American College Testing (ACT) research reveals that too few high school graduates leave high school prepared for college level work in mathematics and science (Camacho & Cook, 2007). Some researchers claim that students are underprepared for college calculus because teachers tend to focus on procedural instruction instead of conceptual understanding (Tall, 1992). Attempts in mathematics education research to understand the complexity of variables that influence teacher's instructional practices, and how these variables impact student achievement, have been largely inconclusive (Mewborn, 2007). What is known, though, is that mathematical understanding and problem-solving ability is primarily shaped by the difference in mathematics proficiency between the students of high school teachers who heavily emphasized calculator usage in the classroom, and those who were the students of teachers who de-emphasized their usage.

IV DATA AND METHODS

The data used in this paper are from the Factors Influencing College Success in Mathematics (FICSMath) study conducted by the Science Education Department at the Harvard-Smithsonian Center for Astrophysics. The data were collected through a questionnaire containing 61 questions that was distributed in the fall semester of 2009. The researchers obtained a stratified, national random sample of 10, 437 students (10,082 of whom completed the course and earned the grade) enrolled in 336 college calculus courses/sections at 134 institutions of higher learning. Data were collected on students grades in college calculus, their mathematics preparation, and demographic information was collected. The survey was pilot-tested with 45 students at two local institutions.

For the sample selection, the distinction between 4 and 2-year institutions served as the first stratification criterion. Each of the two groups was further stratified by the size of the institution (small, medium, and large). The National Center for Education Statistics (NCES) transmitted a table of 4,305 degree-granting post-secondary institutions in the U.S., which included 1,668 2-year and 2,637 4-year schools.

Of the 276 institutions contacted, 182 (65.9%) initially agreed to participate. In the end, the study received usable student questionnaires from 134 (i.e., 73.6% of those who agreed to participate or 48.6% of all contacted institutions).

Dependent Variable.

The dependent variable of interest for this study is the final grade in the first-year college calculus course. The grade in the calculus course was recorded on a 100-point scale. After students completed the FICS Math survey, instructors held onto the surveys until the end of the semester and then recorded the course grade of each student on the questionnaire (Barnett, Sonnert &, Sadler, 2012). In instances where instructors provided letter grades instead of a number, grades were converted using the following scale: A+ = 98, A = 94.5, A- = 92, B+ = 88, B= 84.5, B-=81, C+=78, C=74.5, C-=71, D+=68, D=64.5, D-=61, F=40. Three students who received a passing grade were assigned a grade of 83. In the few cases where students received slightly more than 100 points, their grades were reset to 100. The mean grade was 79.6. The standard deviation of final course grades was 14.6. The distribution of grades is shown in Figure 1.

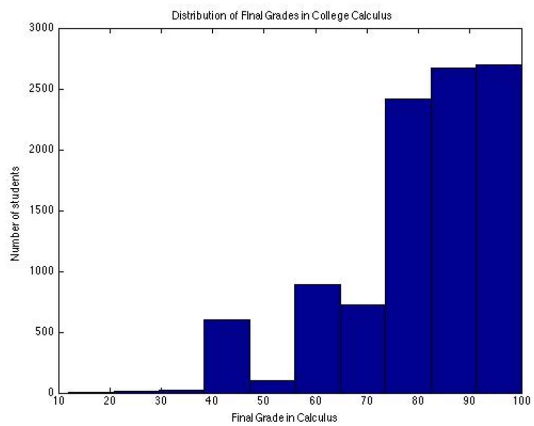

Figure 1: Distribution of final grades in first-year college calculus.

Independent Variables.

The independent variables of interest were those describing calculator use in the students highest mathematics class in high school. These variables were: q16after, q16derivint, q16exam, q16graph, q16home, q16simple, q16trig, q17compl, q17graphcalcl, q17onlinel, and q25nocalc. The variables prefixed by q16 are used to identify students who were allowed to use a calculator in the most advanced high school math course only after the technique had been practiced with paper and pencil, for derivatives and integrals, for exams, for plotting graphs of functions, for homework, for simple calculations, and for trigonometric functions, respectively. The variables prefixed with q17 are used to identify the frequency at which students were allowed to use computers in their most advanced high school math course and the frequency at which they used graphing calculators in their most advanced high school math course, respectively. Q25nocalc identifies students who were required to take tests or quizzes in their most advanced high school math courses that required calculations without calculators. 78.5% of all students in our survey used graphing calculators in their most advanced high school mathematics classes. 15.3% reported using non-graphing calculators in the highest-level mathematics course, and 6.2% did not use calculators at all in the most advanced high school mathematics course.

Additional Variables.

Control variables included gender (male = 0, female = 1), race/ethnicity, parental socioeconomic status, whether college-level calculus was taken in high school, and SAT/ACT mathematics score. As we move forward, we will also look at students who only took as advanced as Algebra and Trignometry/Pre-Calc in high school.

For this project, we distinguished four categories of race/ethnicity: white, black, Asian/Pacific Islander, and Hispanic. Students who reported they were Hispanic were identified as such, while non-Hispanic students were categorized according to what other race they indicated. Asian and Pacific Islanders were combined into one category. For numerical reasons, the few students who identified as Indian/Alaska Native or other were omitted from our analysis.

Education of both parents was used as a proxy for socioeconomic status. Students indicated their parents' highest level of education on the following scale: 0 = did not finish high school, 1 = high school graduate, 2 = some college, 3 = 4 years of college, and 4 = graduate level education.

Methods

In order to test the relationship between high school calculator variables of interest and the final college calculus grade, we ran multiple linear regression models of the final course grade, controlling for the aforementioned variables. We considered both main effects and interactions effects models. The regression analysis was preceeded by a factor analysis, with the goal to reduce the 11 calculator variables into a smaller number of composites. These composites are formed from the original variables that load on (correlate with) the same latent factors, respectively. In a factor analysis, there are the same number of factors as there are variables. Each factor encapsulates a certain amount of the overall variance in the observed variables. And the factors are listed in order of how much variation they explain.

The Factors that explain the least amount of variance are generally discarded. A factor loading correlation greater than +/- 0.5 is usually required (Rahn) for the factor to be considered. From Figure 2, we see that Factor 1 (F1) has 7 variables that load on it, and

Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9
q25nocalc	0.146	-0.639	0.665	-0.325	-0.081	0.033	-0.064	-0.104	0.01
q16after	0.118	-0.755	-0.228	0.559	0.217	0.051	-0.042	-0.023	-0.016
q16derivint	-0.555	-0.289	-0.35	-0.132	-0.524	-0.295	-0.325	0.02	0.028
q16exam	-0.717	0.175	0.207	0.241	0.089	-0.185	-0.009	-0.434	0.352
q16graph	-0.716	-0.218	-0.053	-0.199	0.226	-0.018	0.228	0.418	0.345
q16home	-0.639	0.149	0.434	0.323	0.06	-0.302	-0.099	0.276	-0.31
q16simple	-0.653	0.097	0.118	0.169	-0.229	0.648	-0.208	0.07	0.033
q16trig	-0.7	-0.169	-0.105	-0.049	-0.194	0.065	0.557	-0.192	-0.28
q17graphcalcl	-0.626	-0.05	-0.203	-0.352	0.521	0.07	-0.289	-0.167	-0.228

Figure 2: Unrotated Factor Analysis of Calculator Variables of Interest.

Factor 2 (F2) has two significantly correlated variables. We named F1 zealotry because the variables that loaded onto it related to the pervasiveness of usage of the calculator in high school. F2 was named restricted based on the nature of the variables which correlated with it. 17compl was disregarded, as the factor analysis determined that it did not significantly assist in explaining the latent relationships of the model. This makes sense because this variable relates to computer-usage in the classroom, but we are focused on calculator usage.

While Figure 2 shows an 'unrotated' factor analysis, as we move forward with this research, we must choose an oblique-rotation factor analysis. It is simplest and easiest to interpret. The 'unrotated' factor analysis initally seperates the variables according to their respective variances. It defines the widest net of "linkages" or the greatest order and patterns in the data (Rummel). An oblique rotation, however, would further define the groups delineating the interrelated data. An orthogonal rotation in this context would not have made sense, as it is based on the assumption that the initial variables are not correlated, and we know that this is simply not the case given the nature of our data.

Note that I used MATLAB R2013b for all statistical analysis previously mentioned and to come. To create the new factor variables (F1 and F2), we averaged the necessary old variables (making sure they were previously standardized) that corresponded to each Factor, F1 and F2, and we then re-standardized the end results for ease of interpretation. To account for missing values, we employed a list wise deletion method that deleted each row that contained a missing value. In all, we deleted 524 cases.

V RESULTS & CONCLUSION

Results

From solely our main-effects model (Figure 3), we determine that both the zealotry and restricted variables are statistically significant, but this model only explains 0.5% of the overall variance in the entire model. We do find, however, that our control model (Figure 4) explains roughly 10% more of the overall variance. Additionally, we observe from the main effects model that for every standard deviation increase in zealotry, the average score decreases by 0.36 percentage points. For the same increase in restrictedness, the grade increases by over a full percentage point.

```
Linear regression model:
    y ~ 1 + x1 + x2

Estimated Coefficients:
                     Estimate       SE        tStat       pValue
    (Intercept)        79.606     0.14439     551.33              0
    x1  Zealotry     -0.35649     0.14461    -2.4652        0.01371
    x2  Restricted      1.049     0.14455     7.2571     4.2436e-13


Number of observations: 10133, Error degrees of freedom: 10130
Root Mean Squared Error: 14.5
R-squared: 0.00599,  Adjusted R-Squared 0.00579
F-statistic vs. constant model: 30.5, p-value = 6.2e-14
```

Figure 3: Main-Effects Model

When we only view the controls (Figure 4), expected grades differed by race. Particularly, only students identifying as African American seem to have a significant effect on the control model. Additionally, both the gender and the year in college of the student are significant. Gender (categorical variable) negatively affects the final calculus course grade only if the student is female and has no affect if the student is male.

```
Linear regression model:
    y ~ 1 + x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8 + x9 + x10

Estimated Coefficients:
```

	Estimate	SE	tStat	pValue
(Intercept)	58.241	1.2756	45.657	0
x1 **q7calc**	1.5778	0.24209	6.5175	7.6335e-11
x2 **q46gender**	-4.1724	0.33691	-12.384	7.1846e-35
x3 **q48hispanic**	-0.41781	0.72878	-0.57331	0.56646
x4 **q47asian**	1.1109	0.79974	1.3891	0.16484
x5 **q47black**	-2.2709	0.93216	-2.4362	0.014868
x6 **q47white**	0.76292	0.68713	1.1103	0.26691
x7 **q50collegeyear**	-0.32243	0.14424	-2.2354	0.02542
x8 **q54edfather**	0.15457	0.16549	0.93403	0.35032
x9 **q55edmother**	0.25518	0.1795	1.4216	0.15517
x10 **q58act_satm**	0.037151	0.0017189	21.613	2.0175e-100

```
Number of observations: 7205, Error degrees of freedom: 7194
Root Mean Squared Error: 13.5
R-squared: 0.102,  Adjusted R-Squared 0.1
F-statistic vs. constant model: 81.3, p-value = 4.17e-159
```

Figure 4: Control Model

The further along a student is in college, the greater the negative impact on their final grade. That is, for every 1-year increase in college, the student's final calculus grade decreases by .032 points. Student SAT/ACT score and whether or not students have taken a college-level calculus course prior to college also significantly effect the final course grade. A one standard deviation increase on the SAT/ACT corresponds to a .04 percentage point increase on the final college calculus grade. When we combine both the main-effects and control models (and only include the significant controls), we determine that all aforementioned control variables, zealotry, and restrictedness are statistically significant; furthermore, the model explains 10.3 % of the variance in students final course grades. The significant controls are shown in Figure 5.

```
Linear regression model:
    y ~ 1 + x1 + x2 + x3 + x4 + x5

Estimated Coefficients:
                     Estimate       SE          tStat       pValue
    (Intercept)        59.397      1.0971      54.138              0
    x1q7calc           1.5996     0.24034      6.6557     3.0235e-11
    x2q46gender        -4.235      0.3343     -12.668     2.1377e-36
    x3q47gender       -3.1565     0.73884     -4.2723     1.9595e-05
    x4q50collyear    -0.33328     0.14317     -2.3279       0.019945
    x5q58act_satm    0.038164   0.0016643      22.931    1.9619e-112


Number of observations: 7321, Error degrees of freedom: 7315
Root Mean Squared Error: 13.6
R-squared: 0.1,  Adjusted R-Squared 0.0993
F-statistic vs. constant model: 162, p-value = 2.73e-164
```

Figure 5: Multlinear Regression of only the significant control variables

This model containing only significant control variables explains 10% of the overall variance, almost 10% more than our main effects model. From the main-effects model, we see that the zealotry variable is barely significant (p-value < 0.063), but the restricted variable is extremely significant (p-value < 0.000012). When we combine both the main effects model and the control model, we observe roughly the same relationship (Figure 6), with the zealotry variable's p-value increasing to 0.074 and the signficance of the restricted variable decreasing but still remaining statisticlaly significant.

```
Linear regression model:
    y ~ 1 + x1 + x2 + x3 + x4 + x5 + x6 + x7

Estimated Coefficients:
                      Estimate       SE          tStat       pValue
    (Intercept)         59.733      1.0977      54.417              0
    x1 q7calc           1.5668      0.2401      6.5257      7.219e-11
    x2 q46gender       -4.2699     0.33412     -12.779     5.3051e-37
    x3 q47gender       -3.2995     0.73876     -4.4663     8.0768e-06
    x4 q50collyear    -0.29972     0.14352     -2.0884       0.036796
    x5 q58act_satm    0.037595   0.0016683      22.534    9.0214e-109
    x6 Zealotz        -0.31325     0.17582     -1.7816       0.074853
    x7 Restrictedz     0.68937     0.16148      4.2691     1.9873e-05


Number of observations: 7321, Error degrees of freedom: 7313
Root Mean Squared Error: 13.5
R-squared: 0.103,  Adjusted R-Squared 0.102
F-statistic vs. constant model: 120, p-value = 3.53e-167
```

Figure 6: Multlinear Regression of the significant control variables and the main effect variables

```
Linear regression model:
    y ~ 1 + x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8

Estimated Coefficients:
                      Estimate       SE          tStat       pValue
    (Intercept)         59.721       1.0974      54.419               0
    x1  q7calc          1.5653      0.24004       6.521      7.4511e-11
    x2  q46gender       -4.297      0.33428     -12.855      2.0571e-37
    x3  q47black       -3.3198      0.73864     -4.4946       7.079e-06
    x4  q50collyear   -0.30805      0.14353     -2.1462        0.031891
    x5  q58act_satm   0.037753    0.0016695      22.613     1.7218e-109
    x6  Zealotz        -0.3845      0.17888     -2.1495         0.03163
    x7  Restrictedz    0.62349      0.16433      3.7942      0.00014931
    x8  ZxR            0.36909      0.17183       2.148        0.031746


Number of observations: 7321, Error degrees of freedom: 7312
Root Mean Squared Error: 13.5
R-squared: 0.103,  Adjusted R-Squared 0.102
F-statistic vs. constant model: 105, p-value = 4.06e-167
```

Figure 7: Interactions Model with Controls

And after running an interactions model analysis (note that our model only accounts for whether students took calculus in high school), we determined that the only significant interaction was that between the zealotry and restricted variables, with a p-value of 0.035. (Figure 7)

Our focuses of interest are the effects of zealotry, restrictedness, and their interaction term on the students final course grade. We see that, controlling for the standard variables, the more zealous a students teacher was in high school with calculator usage, the lower their final course grade. But the more restricted the teacher was with the calculator usage, the higher the students final course grade. Figure 8 graphically represents the interaction effects between zealotry and restrictedness. When looking strictly at unrestricted usage, we see that lower calculator usage leads to a final calculus grade of roughly 80.5, approximately 1 point higher than the mean grade (79.6). Higher usage, however, leads to a grade of about 78.2, more than 1 point lower than the mean grade. The restricted branch of the graph mitigates this effect of higher usage, with the final course grade being roughly the mean grade. Please note that for our interactions plot, we chose 'low use' to correspond to a standard deviation of -1 and high use to correspond to a standard deviation of +1, where the variables were standardized.

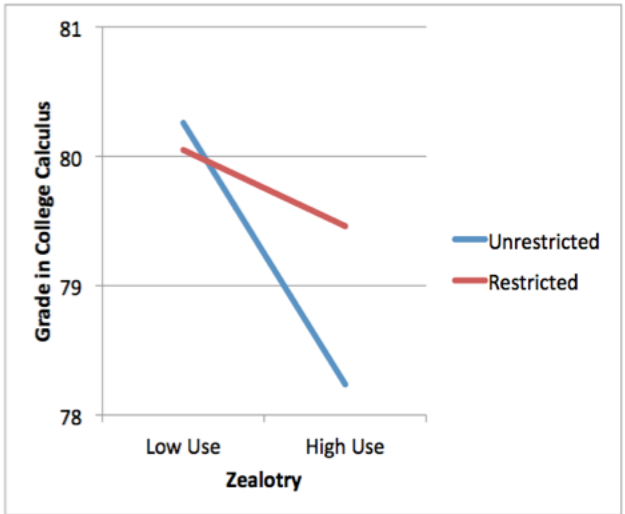

Figure 8: Interaction Effects Plot for Students who took Calculus as most advanced mathematics course in high school

Discussion

Interestingly enough, in our current model, African American was the only ethnicity that was statistically significant; however, this was not the primary aim of this study. We note, nonetheless, that in terms of the importance for the profile of student use of calculators in the learning of mathematics in high school, race and ethnicity is an individual factor worthy of future consideration even though it is secondary in general to mathematics coursework (Crowe and Ma, 2010). Similarly for gender, student year in college, and SAT/ACT scores, while these variables are not at the center of this paper, they still warrant further research and evaluation. At least for gender, Shamoail and Barkatsas (2011) find that boys often expressed greater confidence than girls in technology use in mathematics learning, so it is conceivable that such a relationship is the reason why whether or not a student identified as female has a negative or negligible effect on the overall final calculus grade.

Our main findings provide support for exactly the opposite of the conservative faction of the Math War's beliefs: the more frequently students use calculators in high school, the less successful they are in college-level calculus. Simmt (1997) corroborates our conflicting results by asserting that, to date, [calculators] have not had much of an impact in mathematics classrooms. Crowe and Xin Ma (2010) further substantiate our findings. They claim that calculator usage is feared to weaken common computational skills of students and develops their dependency on these tools. Burrill and Breaux (2002) suggest that while handheld technology should routinely be a part of the learning process of mathematics, the frequency and quality of the use of calculators needs to also be taken into account. This assertion goes hand in hand with the degree of restrictedness we found in the usage of calculators. The students of certain high school teachers that allowed them to use calculators only after they had mastered a technique prove, at least here, better off than their counterparts who were allowed to use these tools for a vast array of tasks unrestrictedly. Secondary school teachers rightfully complain, then, that students lack the basic computational and arithmetic skills needed to succeed in higher education due to calculator dependency (Klein, 2001), and our findings support this claim.

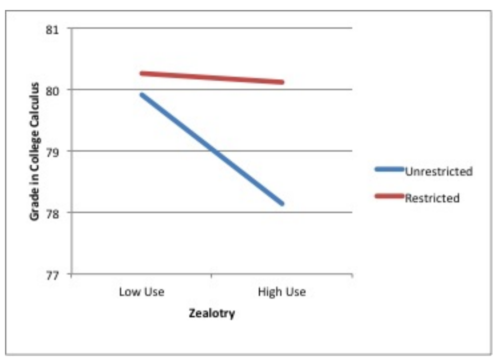

Figure 9: Interaction Effects Plot for Students who took Pre-Calculus as most advanced mathematics course in high school

In order to compare the overall impact of the interaction effect between the zealotry and restricted terms, we ran the same procedure for students who only took pre-calculus as their most advanced mathematics course in high school. It is revealed that the same relationship holds (Figure 9). That is, lower calculator usage (standard deviation of -1) on the unrestricted branch corresponds to a final calculus course grade of approximately 80, while higher calculator usage (standard deviation of +1) corresponds to a grade of 78. On the restricted branch, low usage corresponds to a grade of approximately 80.2, while higher usage yields a grade of 80.1. For pre-calculus students, the drop in the final grade from lower to higher usage on the restricted branch is mitigated even more than for their calculus counterparts.

A common concern that has already surfaced is whether or not the one point percentage difference in final grades is signficant. However, in the context of this study in which there are many more control variables, environmental factors, and latent effects to consider, this result is still unnerving and comes about after the NCTM's push for technology in high school because it is assumed to be useful. We have only begun to crack the surface of a monolith that deserves much more attention and future research.

VI Conclusion

Using data from the Factors Influencing College Success in Mathematics (FICSMath) study, we attempted to understand how certain variables of calculator usage in high school affect students final course grades in first-year college calculus.

Not surprisingly, we found that the control variables of race, gender, year of college student, SAT/ACT math scores, and whether or not students had prior experience with college-level calculus affected their final course grades. Our main result was that the frequency of use of calculators in high school could be, in some respects, detrimental to students' later success, particularly for students who had teachers that were overly zealous with calculator usage in high shcool. We also found that a high degree of restricted use helped to alleviate the adverse effect of zealotry. This relationship even holds for students who took pre-calculus in high school as their most advanced mathematics course.

This result goes against the NCTM's standards of mathematics teaching. The very technology they are trying to emphasize could, in fact, be worse for students. By contrast, our finding lends support to the anti-calculator faction of the Math Wars.

The American schooling system has been struggling to keep up with its international competitors as of late (specifically in the sciences and mathematics). While many have assumed that technology would be beneficial in the aim to attract and retain top-notch STEM students, perhaps they are wrong. Perhaps mathematics teachers across the country should rethink how they integrate calculators into the classroom and should go back to the drawing board in order to create lessons that make better use of this technology.

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APPENDIX

	Number of Students	Percent
Yes	7,610	73.38%
Not selected	2,759	26.60%

A. -- Q16After Frequency Table

	Number of Students	Percent
Yes	6,633	63.96%
Not selected	3,736	36.02%

B. -- Q16derivint Frequency Table

	Number of Students	Percent
Yes	2,525	24.35%
Not selected	7,844	75.63%

C. – Q16exam Frequency Table

	Number of Students	Percent
Yes	2,861	27.59%
Not selected	7,508	72.39%

D. – Q16graph Frequency Table

	Number of Students	Percent
Yes	1,241	11.97%
Not selected	9,128	88.01%

E – Q16home Frequency Table

	Number of Students	Percent
Yes	2,930	28.25%
Not selected	7,844	75.63%

F – Q16simple Frequency Table

	Number of Students	Percent
Yes	3,827	36.90%
Not selected	6,542	63.08%

G—Q16trig Frequency Table

	Number of Students	Percent
Yes	2,525	24.35%
Not selected	7,844	75.63%

APPENDIX

Days of School Year	**Number of Students**	**Percent**
0	6,109	59.69%
4	2,382	23.28%
9	753	7.36%
36	596	5.82%
180	392	3.83%

H – Q17CompLinearized

Days of School Year	**Number of Students**	**Percent**
0	1,305	12.63%
4	773	7.48%
9	556	5.38%
36	3362	32.54%
180	4333	41.94%

I – Q25GraphCalcLinearized

Days of School Year	**Number of Students**	**Percent**
0	8,058	78.73%
4	695	6.79%
9	201	1.96%
36	478	4.67%
180	801	7.83%

J – Q25OnlineLinearized

	Number of Students	**Percent**
Yes	2,892	28.42%
Not selected	7,282	71.56%

K – Q25NoCalc

L - Hard copy of the FICSMath Survey Available

		Unrestricted	**Restricted**
Zealotry	**Low Use**	80.26	80.05
	High Use	78.24	79.46

M – Interaction Effects Table for Students who Took College-Level Calculus as their most Advanced Mathematics Course in High School.

APPENDIX

		Unrestricted	Restricted
Zealotry	**Low Use**	79.9	80.26
	High Use	78.14	80.11

N – Interaction Effects Table for Students who Took Pre-Calculus as their most Advanced Mathematics Course in High School