Examining the Efficacies of High School Calculus Programs

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Abstract

The focus of my thesis is the International Baccalaureate program, which is a high school diploma program which emphasizes academic rigor and intercultural understanding among its main tenets. I had two goals in this thesis: first, to investigate the characteristics of students who took calculus in the International Baccalaureate program and compare them to students who took calculus in other high school programs and to students who took no calculus at all before taking it in college; and second, to probe what kinds of differences exist in students' performance on their first college calculus courses based on the type of high school calculus course they had taken, if any. I used data from the FICSMath survey to perform these analyses. The results included some anomalous findings in the demographic makeup of the IB student sample, notably in the racial profile of the group. I also found links to the IB origins as a program to accommodate international students. In answering the second research question, I found that the performance of the IB students was not significantly different from that of other students who had previously taken calculus in high school; the only group which performed significantly differently from the IB students was those who had had no prior calculus experience before taking their first college calculus course. All of my main effects variables were significant in the regression model, and there were no significant interaction terms.

I. Introduction and Motivations

Special academic programs for gifted and advanced students have held a place in American schools since the 19th century, when gifted and talented programs emerged. Advanced coursework is seen as highly favorable in many universities' admissions policies. However, such specialized programs have fluctuated with the times; gifted and talented educational programs in particular have experienced a demise since 1988 (Dougherty 2014). Advanced programs still thrive in other forms, however, and it can be said that they are even more popular today than ever.

Modern high school education is marked by a divergence into ever more specialized and individualized paths. Recent years saw the formation of the AVID program, and the Cambridge International Advanced Subsidiary Levels (AS-Levels) and Advanced Levels (A-Levels) was piloted between 1997 and 2000 and continues to receive legislative support and funding in Florida (Stuart et al. 2014). Other academic programs such as Advanced Placement and International Baccalaureate have received national attention in recent years, and they have been accepted and recognized to the extent that prestigious universities consider graduates of these programs to be desirable (Luo 2013). In fact, over the years from 1997 to 2005, there has been a 111% surge in the number of AP students, and the number of IB students also increased by 74% from 2003 to 2008. For each program, the amount of government funding provided rose accordingly (Luo 2013). President George W. Bush's "No Child Left Behind" policy recommended that all students be presented the opportunity to participate in advanced programs, and it granted a 73% budget increase for the support of Advanced Placement and International Baccalaureate programs, for the sake of teacher training (Wilkerson

2005), while also placing a heavy emphasis on remedial programs so that underperforming students would improve to meet statewide expectations (Blake 2012). In addition to the Bush administration's 2001 decision to issue 1.2 million dollar grants to low-income IB schools, the education budget of 2006 promised $52 million to expand both AP and IB programs in public schools. The 2008 Race to the Top initiative by President Obama specifically cited IB as being a worthy project to be used for school reform (Lope). It is evident that there is much time, energy, and money invested in these programs, necessitating some investigation into the actual benefit, both absolute and relative, that these programs provide to students and schools.

A. The Advanced Placement program

The College Entrance Examination Board, commonly called the College Board, was founded in 1900 with the purpose of standardizing secondary school course content for the sake of continuity among university level courses (Luo 2013). The organization soon created an entrance exam known as the Scholastic Aptitude Test, commonly known as the SAT, in order to inject some uniformity in the college admission process and to establish some rapport between secondary and university education. The Advanced Placement Program itself was developed in 1952 by a committee of education representatives, as a response to the Ford Foundation's program which awarded university scholarships to high-achieving high school sophomores, and with the goal of retaining gifted students in their home high schools (Kyburg 2007). The curricula were designed to be rigorous enough to be used as a standard for granting college credit; it was used exclusively for the allocation of college credit and placement rather than in admissions (Geiser and Santelices 2004). In 1955 the College Board took control of the

program (Luo 2013), and its inaugural year from 1955 to 1956 saw 1299 seniors take 2199 exams at 104 participating high schools. A total of 130 colleges officially recognized AP credit at the time, and although originally intended for participation by 5% of high school seniors, courses expanded to become accessible to a greater number of participants and a wider age range (Kyburg 2007). In the 1980s, the AP program finally gained a place in highly selective institutions' admission processes, a useful additional tool for distinguishing the best candidates in the growing applicant pool. After dramatic expansion during the 1980s and 1990s, the Advanced Placement program is now perhaps the most popular choice of advanced program in the United States. Its usefulness extends to other functions than what has already been described – the courses offered at each high school can signal the quality of the school's program, as well as indicate necessary reforms and modifications in those schools; students are also presented with the opportunity to choose challenging courses to make themselves better candidates for university admissions. Thus, it is no huge surprise that AP courses have been implemented in thousands of schools around the nation and that the majority of universities pay special attention to AP and other similar advanced courses in admissions, though the particular details of their deliberation process varies among institutions (Geiser and Santelices 2004). Students have the option of electing to take as many of these courses as desired, and also of taking Advanced Placement exams which may or may not correspond to the subjects taken in school. These exams are graded on a scale of 1 to 5. There are 31 courses currently offered in the program as well as subject examinations at over 12,000 American public high schools (Luo 2013). In 2010, over 1.5 million students in the nation had taken at least one such exam, more than doubling the

number from 10 years earlier, according to the College Board, which claimed a statistic of 1229 students at the beginning of its existence in 1955, and some 844,741 students as of 2003 (Vanderbrook 2005). There are some unintended but clear problems with the program, however, as not all students have access or the means to participate; in fact, there are demographic and socioeconomic disparities which set some portions of the population at an advantage in these respects over others, as some of the results of this paper will mention. In fact, the American Civil Liberties Union filed a lawsuit against the State of California – Daniel vs. California, 1999 – as a result of these disparities, claiming that the state did not provide sufficient access to AP courses in all schools, resulting in a large, state-funded endeavor to expand the program in underperforming schools and rural areas. In addition, Geiser and Santelices (2004) mention other problems such as grade inflation and the disproportionately large perceived importance of AP coursework to some students and families.

B. The International Baccalaureate program

The foundation of the International Baccalaureate program was laid long before its official establishment. The concept of the program developed in the early 1920s, with European teachers' interest in forming a high school program and college examination that could be recognized by universities around the world. In 1925, L'École Internationale de Genève (the International School of Geneva) presented the concept of the International Baccalaureate, but this was laid aside until the reappearance of the topic at the 1948 Conference of Internationally-Minded Schools (Luo 2013). The program finally took shape in 1961, with a UNESCO-funded conference to investigate international schools at which an international social studies curriculum had been

developed. The UNESCO funded the subsequent establishment of the International Schools Examination Syndicate (ISES), including the International Schools Association, the International School of Geneva, the European Office of the Carnegie Endowment for World Peace, and Oxford University (Luo 2013), and a set of curricula for a number of general subject areas was finally developed. The 1965 Curriculum Conference in Geneva saw the presentation of the first version of the curriculum, and after additions to the ISES including educators from New York's United Nations International School and the College Board, the organization was formally renamed the International Baccalaureate Organization (Luo 2013). Subsequent steps in the process included perfecting the curriculum and examination system, forming agreements with universities worldwide for IB exam result recognition in admission, establishing a presence in a number of schools where the IB curriculum would be taught, gaining acceptance from parents at those schools, and obtaining funding to maintain the program. The complete curriculum was presented in 1967, and although the initial trial had occurred in 1963, with four students taking a history exam (Duevel 1999), the program did not officially take wing until 1970, when a handful of students exited the program as the first group of IB graduates, more than four decades after the initial conception of the program. The first IB school had been authorized in the US by 1971. Mayer (2008) names a Jefferson High School as one of the first American schools to implement IB as one of three learning initiatives on campus in 1982. The program was then implemented in the Portville School District as a magnet program, constituting part of an effort to desegregate the district and create demographically balanced schools. The district's IB program was then obligated to participate in local publicity and recruitment events to distribute information on the

program, and the district also mailed informational brochures to households in the region. Lope (2014) states that the United States educational system was marked by a shift in goals, from one of assimilation of immigrants to the "American way of life" before World War One to one of building peace through international perspectives, and that the emergence of this mentality in the classroom helps to explain the rapid spread of the IB program in the US. In addition, the Cold War and the launch of Sputnik in 1957 ironically led to a surge in investment in international education, with the National Defense Education Act requiring funding for language and area studies. The dawn of the 1960s finally brought the true beginning of international education as it became implemented in IB.

There are three programs throughout the school years: the Primary Years Programme first, followed by the Middle Years Programme, and culminating in the Diploma Programme, which is the core program completed in the final two years of high school. There is a strong emphasis on the holistic elements of learning, as demonstrated by special IB ideology, including the IB Learner Profile (as well as six "areas of knowledge": mathematics, natural sciences, human sciences, history, the arts, and ethics), a Theory of Knowledge course, and by various extracurricular requirements known collectively as "Creativity, Action, and Service" (time committed to activities which hone creativity, action, and service outside of the classroom). In addition, it features a four-thousand-word academic extended essay in a subject of the student's choice. Courses allow students to choose at least six subjects from one of two levels (Standard and Higher Levels), culminating in an exam which has been standardized to be identical across the world. These exams are graded on a scale of 1 through 7, with 7 being the top grade, and

they, as well as assignments known as Internal and External Assessments, incorporate a transnational grading scheme in which students' work is submitted to certified IB graders in two countries outside the student's own, for the sake of consistency in the grading standards. This strategy maintains a cohesive and unified standard for IB students across the schools of implementation, ensuring a sort of internal validity to the program through its roughly 6500 trained examiners for these "external assessments". IB has come a long way since the 1995-1996 academic year, when its students numbered 775 (Luo 2013). According to one report, the program is offered in 2200 schools and 140 countries, with 120,000 students taking the exams yearly ("A Brief History of IB"). As of the early 2000s, there were reported to be more than 1300 IB schools around the world (Blake 2003). More recently, Lope (2014) counted 1796 IB schools in the country, more than in any other country, noting that the number of IB schools in the US comprised "less than 2% of the total number of high schools in the country, but the IB's influence on American education had grown out of proportion to its numbers".

The International Baccalaureate program has come under attack from certain individuals and communities in the United States, who primarily denigrate the system on ideological grounds, particularly objecting to the program's fundamental "internationalism" being incorporated and taught in schools. There are sites, books, and movements devoted to criticizing the IB for its perceived elitism and anti-American outlook (thetruthaboutib.com). Other downsides of the program include the high cost of IB implementation; the school incurs heavy expenses for application and authorization as well as the costs of training teachers and coordinators. IB and AP exams alike involves a cost to the students.

C. Statement of the problem

It is known that many universities and institutions, including the most prestigious ones, recognize AP and IB applicants as desirable (Luo 2013). Some universities even grant university credits in order to reward students' advanced work during the high school years and to attract such students to enroll. However, there have been suspicions that that this may not be a good strategy, and that granting university credits in this context may be a disservice to students who may benefit from the repeated instruction of the material in university courses (Luo 2013). Such results and debates in addition to the government policies mentioned above have served as part of the motivation for this paper, in the hope of providing some further evidence which may be informative in providing some information on whether or not these programs are effective and worthy of large-scale investment. The National Research Council has stated that "Little evidence is availabl for evaluating the long-term effects of the AP and IB programs. For instance, the panel could not find systematic data on how students who participate in AP and IB fare in college mathematics relative to other students…" (Geiser and Santelices 2004, p. 6).

The objective of this paper will be to examine the quantitative differences, if any, of the grades of university students in their first mathematics course as a function of their participation in IB. It will mainly address the questions: **1) what significant differences, if any, characterize students who participate in the International Baccalaureate program when they are compared to other students who took or did not take calculus in high school before taking college calculus?** and **2) how do the program's graduates perform in their undergraduate calculus courses in comparison to**

students who did not participate in the program? The data are drawn from the FICSMath survey, distributed by the Harvard-Smithsonian Center for Astrophysics to undergraduate students in their first college calculus course.

II. Literature Review

There have been a small handful of studies done in the past which examined the academic performance of Advanced Placement and International Baccalaureate students using various measures and methods. Few have directly compared the efficacies of the two programs, but the results generally tend to give mixed and ambiguous conclusions, particularly in the case of direct comparisons of the two programs. Some claim that IB students are much more likely than others to be successful in university and to be the most successful group in college admissions, while others find no significant difference. Generally speaking, studies so far have found that high school GPA and SAT II scores are the strongest predictors of undergraduate academic success (Luo 2013).

Wilkerson's (2005) study examined the performance of IB students relative to students in the national norm sample on various exam components (SAT Verbal, SAT math, ACT English, ACT math, AP English AP calculus, IB English, IB calculus). This study found t-test evidence indicating significant difference in the two sample groups in the students' respective performance in all components but AP English. The use of courses other than IB exams is useful in parsing IB students' achievement independent of the standards specific to the program. One might attribute this exception to the difference in content between the AP and IB English courses which led to the IB group being at less of an advantage than they were in the other components.

However, Blake (2012) investigated the impact of the IB Diploma Programme on the achievement, as measured by ACT component scores, of students who were identified as being high-scoring. The results showed a correlation between IB

participation and ACT scores in English, reading, and science reasoning, but not necessarily in mathematics. This result stands in somewhat of a contrast to the previously mentioned findings by Wilkerson.

Another study which investigated AP and IB student achievement side by side was carried out in a California State University dissertation. The researcher found no significant difference between them as measured by GPA and by SAT II scores in English and mathematics. In addition, these programs did not reliably predict SAT performance (Luo 2013). It is difficult to reliably conclude from this result how to interpret the result, and it is from uncertainties like these that we derive the motivation to perform further analyses of the achievement of students in the two programs in relation to those who did not participate in either program.

Kobylinski-Fehrman (2013) studied students of the IB Middle Years Programme, hoping to find how low-income students perform on the Criterion Referenced Competencies Test in math and reading, compared to students in a traditional instruction program. When the scores over three years of MYP students were compared to those at the control school, there was found no significant difference in reading, but a significant difference in mathematics in favor of the control – a case in which the traditional system was found to be more efficacious than the IB program school, unlike cases presented in other studies found in this review.

Similarly, pitting AP and non-AP students against each other, Kremers (2010) found no significant difference between the two groups in their post-secondary mathematics achievement as evidenced by earning math credit in their postsecondary paths. There were other independent variables under consideration, such as concurrent

enrollment and high school GPA, but taken in isolation, the AP variable was not found to be a significant factor in this analysis.

Some studies, however, have found evidence of efficacy in these programs: the 2010 International Baccalaureate Global Policy and Research study compared the academic performance of three groups of University of California students from 2000 to 2002. It compared a sample of former IB students, a control group comprising non-IB students who were matched to the IB graduates by demographics, socioeconomic status, and previous academic performance, as well as the rest of the UC population. The researchers found that the IB students' GPAs were 4 to 7 percent higher than the control group and the general UC population, and that their graduation rate was up to 11 percent higher.

Some studies have attempted to link the IB's academic efficacy with its philosophical tenets. Lope's dissertation (2014), concerning itself with the connection between grades and learners' philosophy, probes the relationship between academic performance and students' global-minded outlook as measured on a ranked global-mindedness scale. The English and mathematics grades were found to be significant in predicting scores on global-mindedness, but GPA was not. There seems to be some contradiction here which might be explained by some nuance of the GPA, given that both grades examined were components of students' GPA, but this study provides a point of consideration, seeing as the International Baccalaureate program generally seeks to teach students in a setting of global outlook.

Shaw et al. (2014) compared groups of Florida State University students who had graduated from the AP and IB programs against students who took the Cambridge International Advanced Levels, the traditional British scholastic program administered by Cambridge International Examinations, which, like the IB and AP programs, offers courses and exams by which they are considered for university applications. The researchers were comparing the three groups in a number of variables of interest: the relationship between program participation and university GPA, university engagement (measured by participation in additional programs including individual studies, study abroad, etc.), and university retention rate. All analyses were carried out after accounting for SAT scores at the end of high school and other control variables, and the regressions for each dependent variable were done as a function of hours that each student spent in their respective programs. From a regression with respect to university performance, they found that of the three programs, the AP group had the highest coefficient for GPA boost per hour spent on AP courses, at 0.0156 extra GPA point. This was followed by the AICE (A-level) coefficient of 0.008747, and finally the IB coefficient of 0.005948. This finding would seem to suggest that for each hour spent within the high school program, each group benefitted differentially with the IB group seeing the least efficacy. However, it is important to keep in mind the fundamental differences between the programs. Unlike the AP and AICE programs, IB diploma students are required to take six subjects as a complete set; therefore, the total GPA contribution from the program would likely be larger than the raw data would suggest, since the finding does not account for the total number of hours contributing to the GPA. The same research paper finds the highest probability for AP and smallest probability for the IB group conducting

directed individual studies at Florida State University; again, the largest probability of the AP students and smallest probability of the IB students participating in the university's honors program; and largest probability of AP students and second-largest probability of IB students receiving honors in their majors. However, the IB group was found to have the highest retention of the three, where the AP and AICE groups are seen to have nearly identical coefficients.

Geiser and Santelices (2004) examine the role of Advanced Placement and other such honors courses in admissions to prestigious universities. Although they concede a strong correlation between students' performance on AP examinations and their subsequent undergraduate academic performance, they find that their mere participation in such programs does not reliably indicate or predict their success in college. In several regressions analyzing the relationship of advanced coursework on college grades and persistence, they found that the percentage of variance in first- and second-year college grades was highest in a measure of students' GPA which was unweighted for honors participation, while there was very low predictive power associated with GPA measures which were augmented to account for honors courses. Students' AP exam scores, on the other hand, were found to be strong predictors of subsequent college performance, with higher predictive weight than most other factors, excluding (unweighted) high school grades. This is consistent with research findings which indicate the higher predictive power of specific, college-preparatory subjects such as the SAT II over supposed tests of students' general capacity and aptitude such as the SAT I. The researchers suggest that institutions reconsider the unquestioned status of AP program participation as a criterion in "high stakes" or selective university admissions. In particular, they recommend

solutions such as requiring minimum AP examination scores rather than general AP course participation, considering honors coursework in a local context, and reducing the weight for honors coursework to avoid placing unnecessary and unwarranted weight on participation. In a rebuttal by Camara and Michaelides (2005) of the College Board, some conflicting evidence was cited in response.

III. Analysis and Results

A. The FICSMath survey and methods

The data has been drawn from Factors Influencing College Success in Mathematics, a survey designed and distributed in the 2009 fall semester by the Science Education Department at the Center for Astrophysics to students in their first calculus course at university. Material covered by questions on the survey ranged from demographic data, experiences in high school classes, and students' career aspirations and attitudes toward various STEM subjects. The target schools to which the survey was distributed were randomly chosen and included both two- and four-year institutions across the United States. The participants in total numbered 10492 in 336 calculus courses at 134 institutions. Understanding performance on calculus courses is important because of the subject's status as a natural milestone in mathematics, functioning as a gateway to further mathematics and science courses in the undergraduate years, in addition to being a common requirement for pre-career tracks such as medicine and engineering. After the students finished the courses, the professors marked each student's received grade on their surveys before returning them to the CfA for analysis.

Questions on the survey spanned such topics as demographics, students' interest and motivation for studying science, pre-college experiences and school performance, and future plans and aspirations. The following are some of the most relevant variables used in this analysis:

- Type of calculus experience that students had in high school – categorized into types of high school calculus programs and a group for those with no previous

calculus experience in high school. This was the independent variable of interest. Categories were: Advanced Placement, International Baccalaureate, other honors program, regular (or, no particular advanced program), and no high school calculus experience.

- Demographics, including race, gender, parents' education level, and income of regional inhabitants in their home regions, as measured by per capita and median household income (inferred by matching studetns' reported ZIP codes with information pertaining to each ZIP code, from 1999)
- Academic preparation, including high school math grades and scores from the math component of the SAT or ACT
- Final grade in college calculus course on a 100-point scale, which served as the response variable (chosen as a measure to reflect high school calculus programs' efficacy in preparing students for college calculus)

The analysis presented here is based on the assumption that the distribution of participants is generally reflective of the national population at large, allowing us to draw inferences about the general population. The bulk of the statistical processing has been performed in Microsoft XLSTAT, an Excel add-in feature, as well as in R.

The statistical methods and measures employed in this report include:

- Statistical significance as measured by p-value and standard error overlap
- ANOVA (analysis of variance) and ANCOVA (analysis of covariance)
- Multiple linear regression with and without interaction terms
- Type III F-test

B. Research Question One

Several types of demographic data have been collected to classify participating students. The FICSMath survey takes precautions against demographic stereotype threat in the layout. Social psychologists have affirmed the negative impact of stereotype threat, in which an individual feels at risk of confirming negative stereotypes after being primed with cues which implicitly invoke his or her affiliation in a stereotyped group. In order to reduce such effects and ensure that the students' responses were unaffected by the act of revealing personal information and the consequent subconscious identification with stereotypes related to their mathematical ability, the demographic information is located at the end of the survey so that most students would only answer them after finishing the non-demographic components of the survey.

The following diagrams show the makeup of the participant sample detailing high school program participation, race, gender, and high school type and location. The survey questions about race and ethnicity were modelled after census questions. Racial categorization presented certain difficulties as expected, particularly due to the instruction for students to select all applicable racial categories. Ultimately, students' race was defined by the followed method: if students indicated that they identified as Hispanic, they were classified as Hispanic accordingly regardless of whether or not they indicated any other racial identity. The rest were categorized as non-Hispanic white, non-Hispanic black, non-Hispanic Asian, other racial groups, and "missing" (a nonresponse category for those students who indicated no racial identity). Although this simplification presents certain difficulties, it was necessary to ensure a large enough sample of each category to ensure some level of statistical precision.

The total survey population comprised a majority of male students at about 60% of the participants, with female students forming 34% of the total group and the other 6% representing the nonresponse group. Caucasian students formed about two-thirds of the participants. Even if all of the gender nonresponses are attributed to females, this leaves an unequal gender ratio of 60 to 40 in favor of males, and if half of the nonresponses are attributed to each gender, the male students number nearly twice as many as the female students.

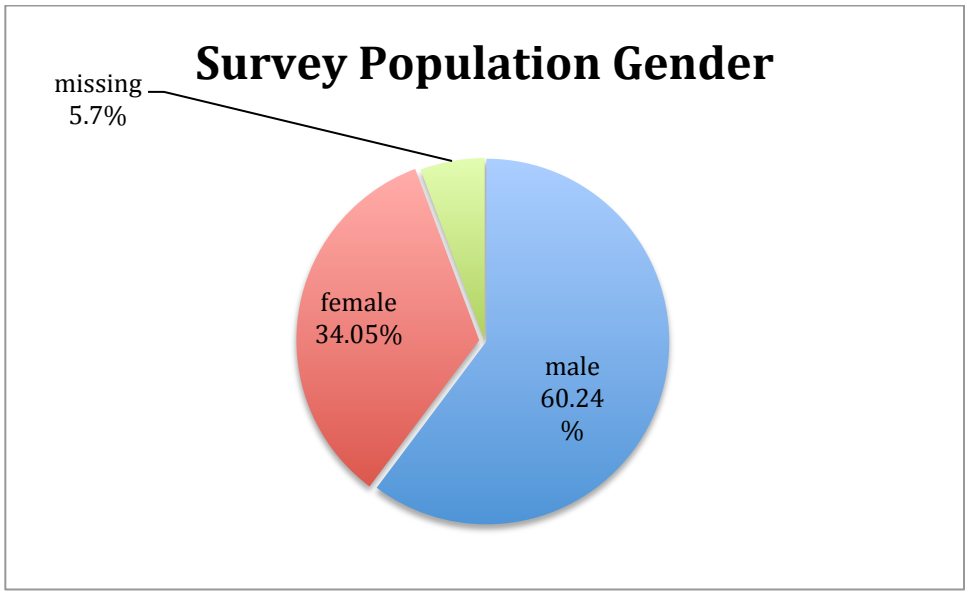


Fig. 1: Proportion of survey population in each program category

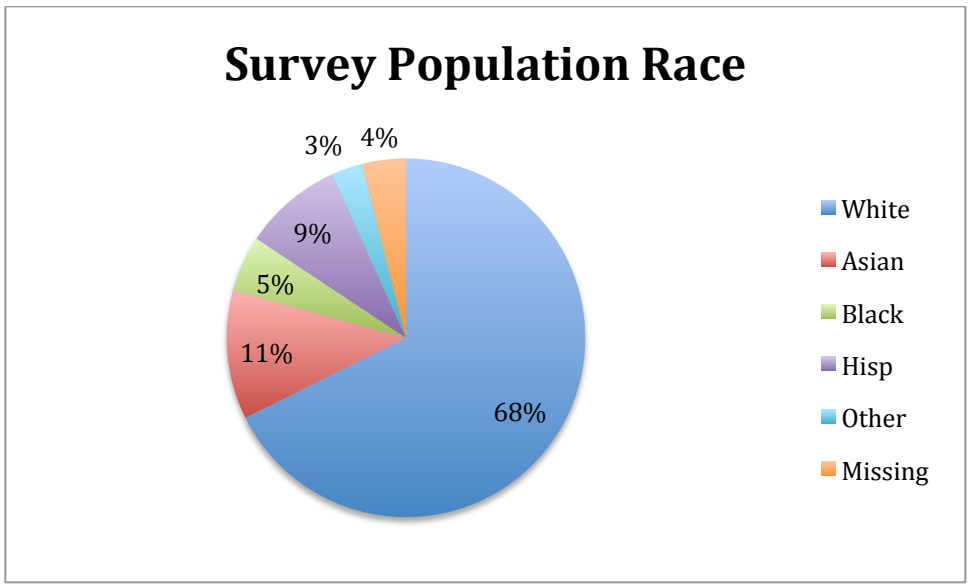


Fig. 2: Proportion of survey population in each racial category.

For a comparison of somewhat limited value, the United States Census Bureau site displays the 2014 percentages of the total American population by race: 62.1% are listed as non-Hispanic white, 13.2% as Black, 17.4% as Hispanic/Latino, 2.5% as multiracial, and 5.4% as Asian. These main categories are taken from the site from among others; these five classes add to 100.6%. This is likely due to a rounding error or a different method of classifying the races, as the lack of categories for other races implies, in addition to the "Hispanic/Latino" combination. Nevertheless, there are some disproportionalities seen in the survey, particularly in the disparity in the percentages of Blacks between the population and the sample. This might be attributed either to a disparity in the proportions of the racial groups in the population versus those who attend college or in the proportions of racial groups in STEM fields. The following graph compares the national population percentages against the proportion of racial groups which participated in FICSMath. It is clear that the White and Asian populations are higher in the survey sample than their nationwide population, while Hispanics and Blacks are underrepresented. The graph includes standard error bars on the data points obtained

from the survey (indicated by horizontal ticks on the points indicating the survey proportions), but they are too small for their span to be seen on the graph, falling far short of overlapping with most of the national proportions. This suggests a highly significant disparity between the national population and their representation in higher education, specifically in calculus courses. Assuming that these results from the survey are reflective of the subset of the general university population who take calculus, these numbers confirm the predominance of Caucasians and males in STEM environments. Thus, these irrefutable underrepresentations in gender and race are reflected as phenomena that begin either in college or perhaps even earlier in the educational trajectory.

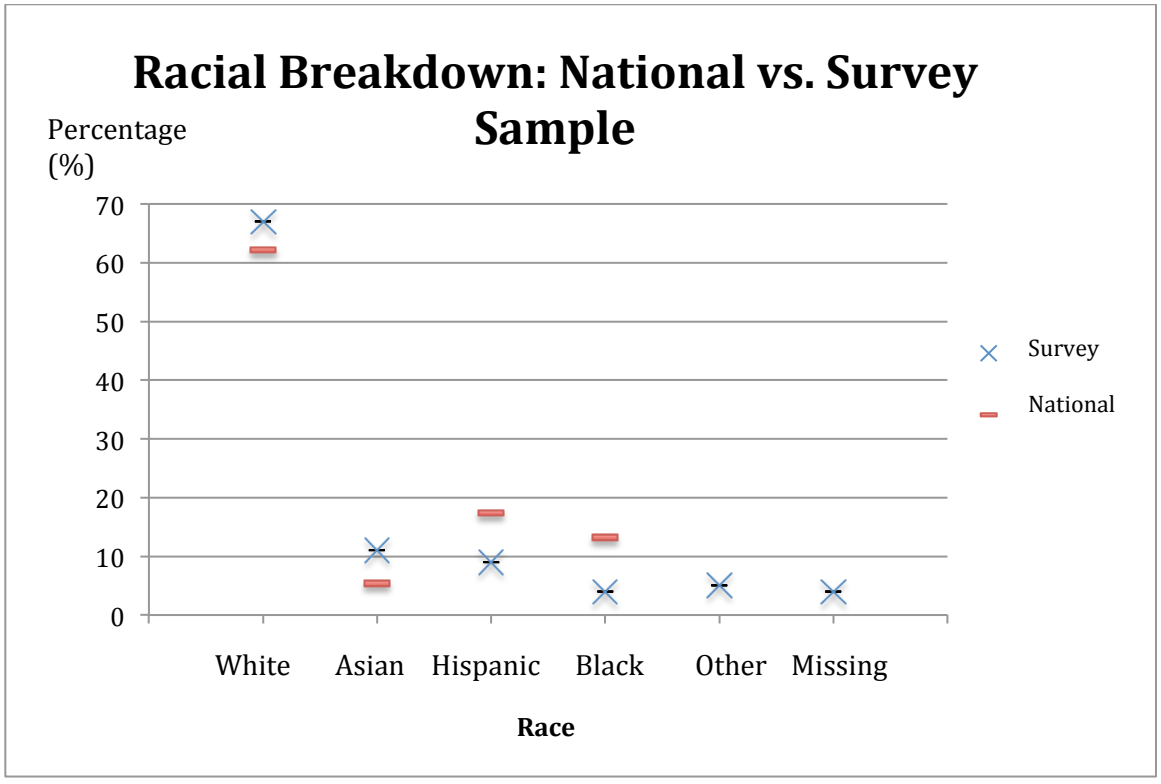


Fig. 3. Racial proportions represented in the survey population and by the United States national population (national information taken from United States Census Bureau).

High school program participation was coded based on students' responses to two questions, one in which they were asked to indicate whether they had taken an AP

calculus course in high school, and the other which was analogous but instead pertained to non-AP (IB, honors, regular) courses in high school. If participants indicated that they had taken both IB and AP calculus in the same high school year, they were labeled as IB, due to the large probability of the students having counted their IB course as being AP in addition regardless of the orientation of the course if they had taken the AP exam. If they had taken IB and AP calculus in different years, they were allotted their own "multiple" program category, and if they indicated multiple non-AP choices, they were placed into one of those categories with the hierarchical scheme of IB taking precedence over honors and regular, and with honors being represented if students indicated both honors and regular calculus. If responses were missing, they were reported as having no calculus experience.

According to this categorical breakdown, about 60% of participants were taking calculus for the first time as college students, and of those who had had calculus experience in high school, the majority were categorized as Advanced Placement, while the IB group comprised only 1% of the survey population. The "multi" program group is shown below to have had 0% of the participants due to the small number of participants (N=6) who responded that they had taken IB and AP calculus in separate years. Due to its extremely small size, it has been eliminated from later analyses for the sake of statistical rigor.

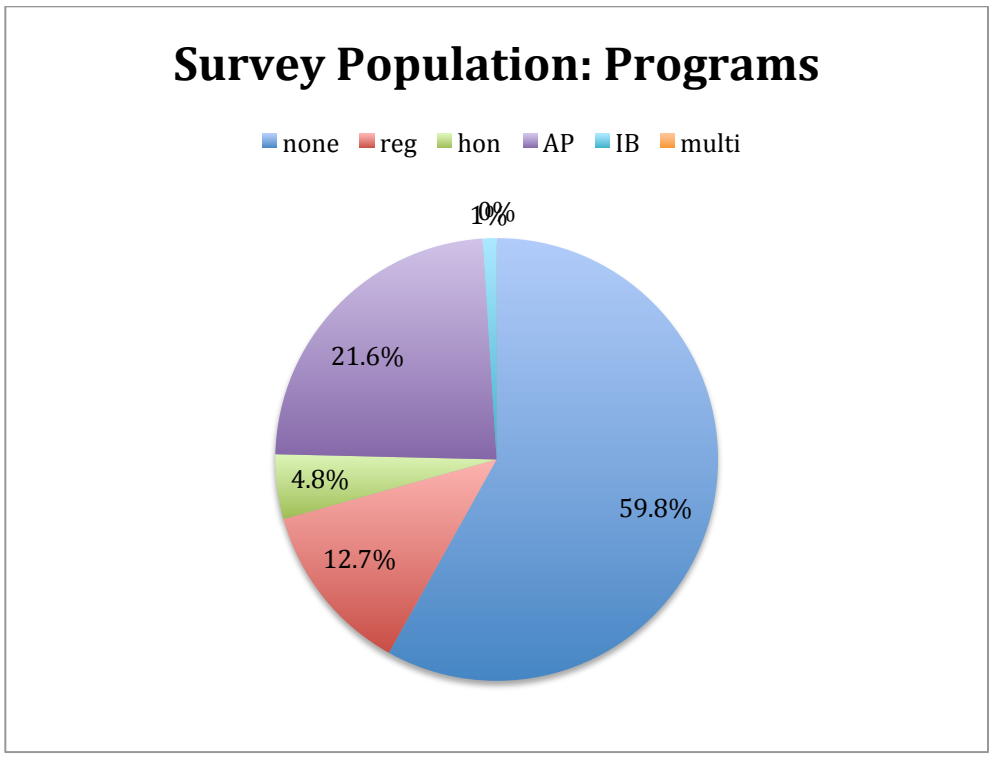


Fig. 4. Breakdown of the survey population by type of high school calculus experience.

A chi-square test of independence shows that there is a statistically significant ($p < 0.0001$) relationship between students' race and the calculus program in which they were enrolled. The chi-square test of independence tests the two categorical variables to determine whether they are significantly related or associated – that is, whether the patterns that emerged in the intersections between the programs and races are likely to have arisen from pure chance, or if there is some underlying association between the two variables. The lower the p-value, the stronger the evidence that there is a dependence between the variables, and the weaker the probability that the relationship between the variables stem from chance. A p-value of less than 0.05 in this and any other test is generally interpreted as the threshold indicating statistically significant results at which we should reject the hypothesis (here, the hypothesis that race and program are independent of each other). Thus, we infer that there is a highly significant relationship

between race and calculus program here. (For further illustration of the use of this statistic, there p-value obtained from a chi-square test of independence between gender and program participation is 0.38 > 0.05, and thus we infer that there is no dependence between gender and high school calculus experience.)

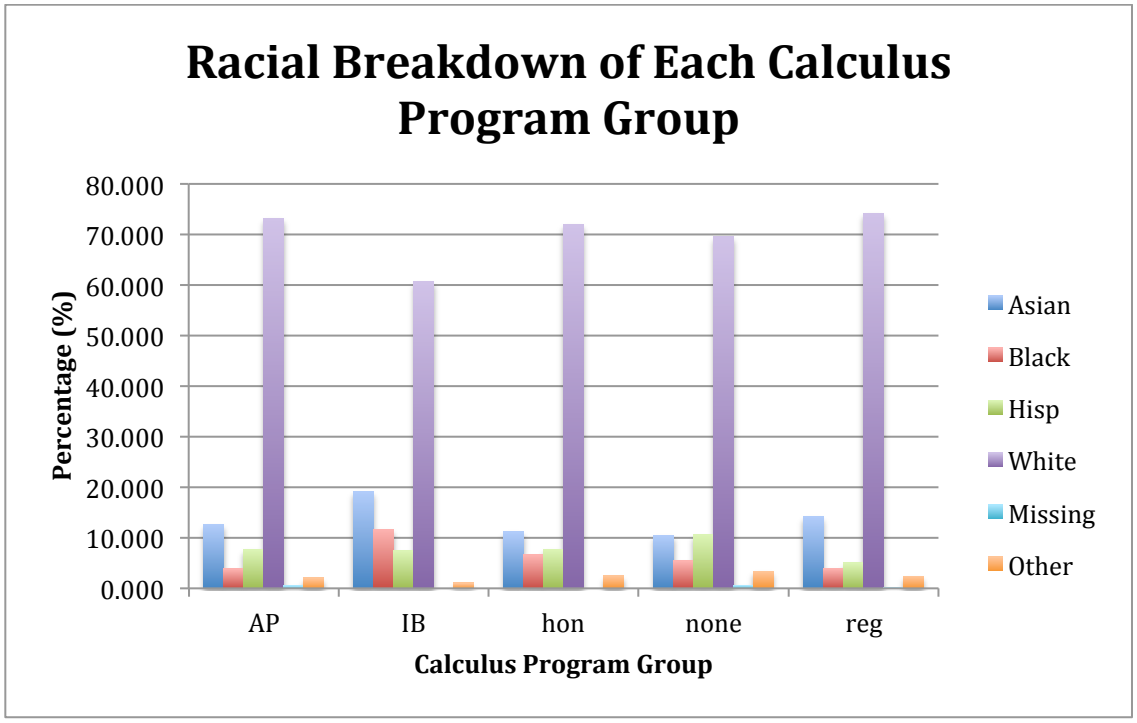


Fig. 5. A breakdown of racial groups among the high school calculus groups – shown as the percentage of each calculus program group who are of each racial group.

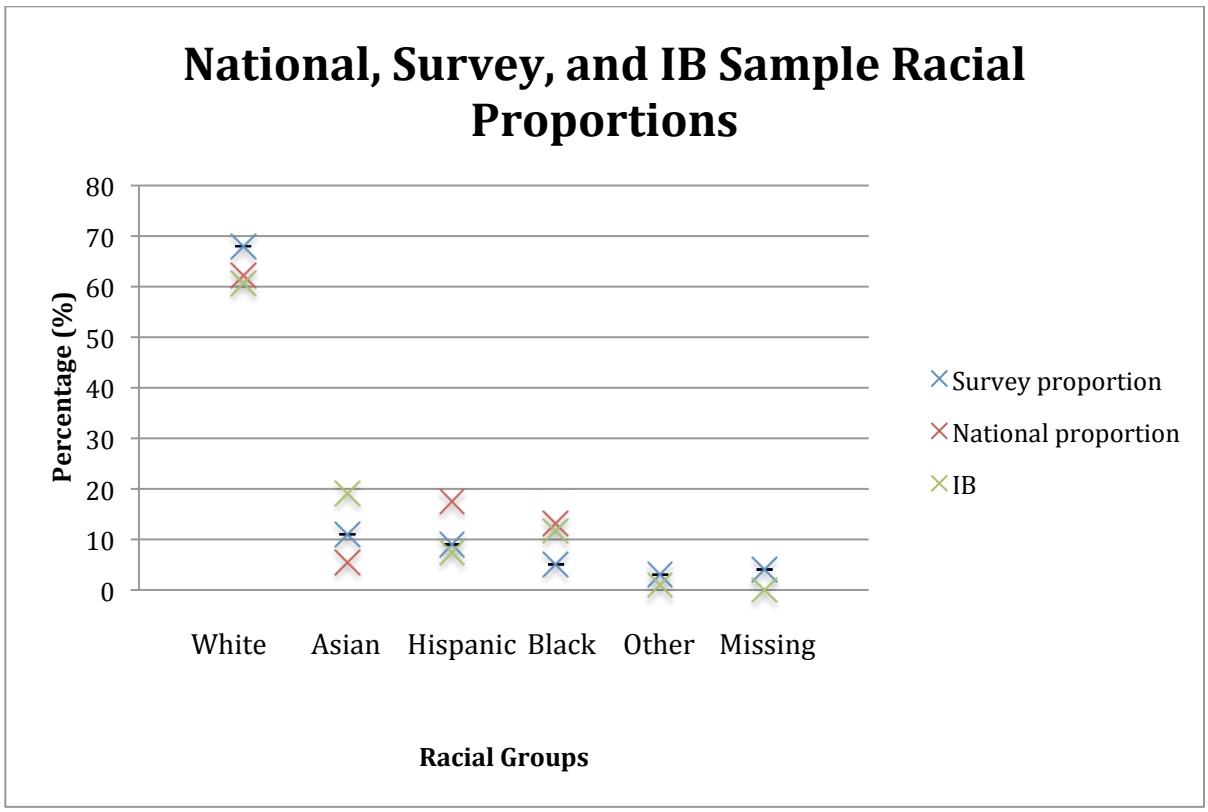


Fig. 6. Proportions of the national and survey populations and the IB sample who belong to each racial group examined. The survey information includes error bars which are too small to be seen.

The next two diagrams represent the dependent, or response, variable in this report: the grades that students received at the end of their college calculus course. The grades were marked on the surveys by the professor after the conclusion of the course, and they are in units of percentage points, as grades marked on a 100-point scheme. These final grades ranged from 12 to 100, with a mean of 79.6 and a standard deviation of 14.6. Figure 7 indicates that the students who had had no previous calculus experience in high school lagged far below their peers in their college courses, while their more experienced classmates who had taken calculus in honors, AP, and IB scored some ten points higher on average. This plot is a "raw" view of the relative grades associated with each program group in this report; the regression later in this paper will present a more detailed analysis of the grades by program affiliation.

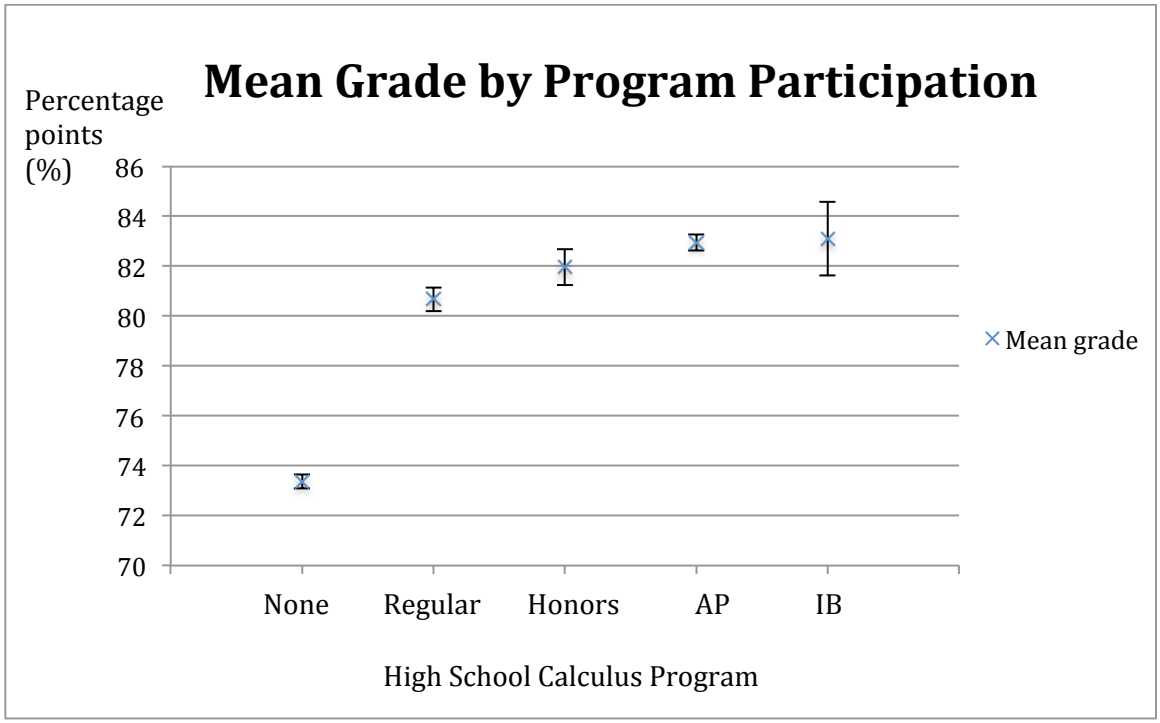


Fig. 7. Plot detailing students' grades in their first calculus courses, by high school calculus experience.

Next, the estimated per capita and median household incomes of the students' residential areas were examined. The students were asked to give the ZIP code of the area in which they had lived in high school, and the researchers later matched the responses to the 1999 income statistics in each ZIP code. This is useful in determining trends in program participation by the socioeconomic status of each student's community. Documenting the regional income data is meant to reveal the socioeconomic profile of schools which offer IB and other programs, which is useful information as the IB program is costly to maintain. It could also potentially provide information on the environment the students lived in and were exposed to. Although there is some risk of inaccuracy in the latter speculation, the regional focus allows for a broader view of the resources available to the participants' schools environments than what the family itself provided, such as the financial resources available to an entire district for implementing

expensive programs such as the International Baccalaureate and Advanced Placement programs in local schools.

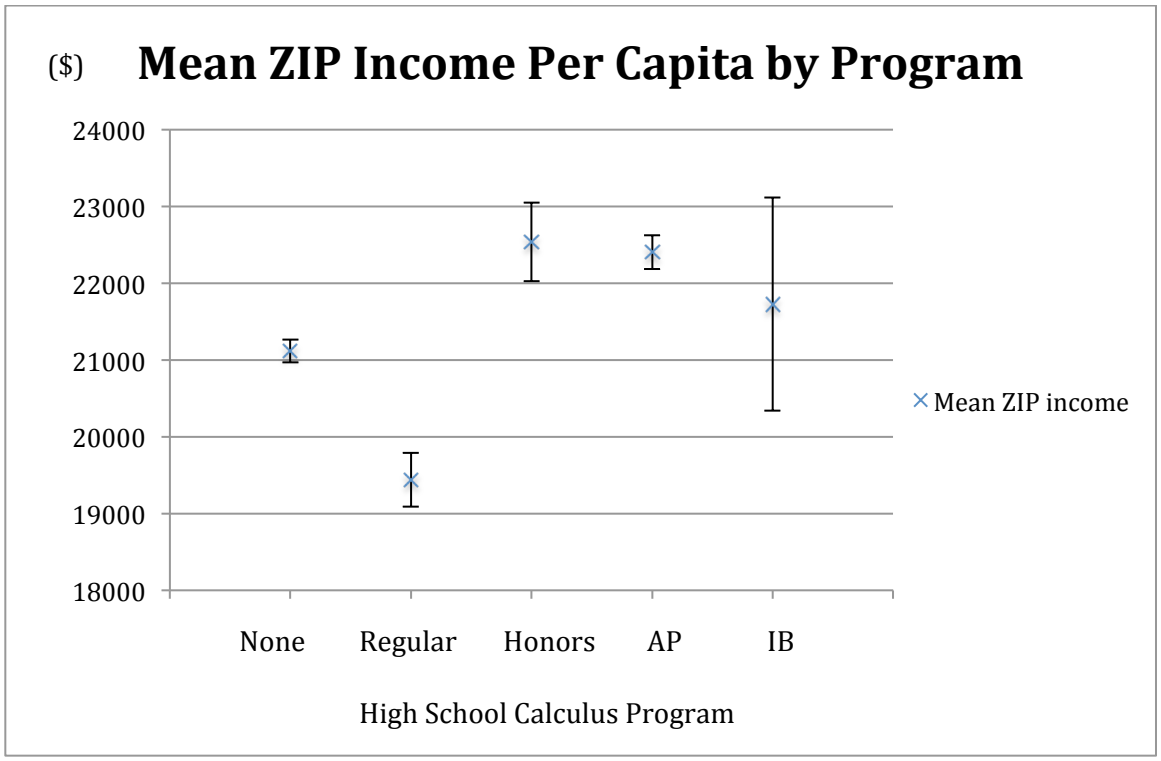


Fig. 8. Plots of mean ZIP income of each high school calculus program group.

It is clear from this graph that the honors and AP groups' mean income were about equal and that the regular program group's mean income was the lowest of the groups studied. The IB group, with its large error bars again due to the small number of constituents, overlaps with the honors, AP, and no calculus groups, so it is possible that their income is comparable to any of those groups' income levels. For a rough reference, I found that the mean per capita income in the United States in 1999 was $30,188 in 2014 dollars (United States Census Bureau, "Income"), which an online inflation calculator equated to $21,244 in 1999 dollars (InflationData).

Students' performance on the SAT and ACT standardized tests has also been included as a control variable, partly to shed another light on academic performance by

program participation. More importantly, however, it functions as a standardized measure of students' incoming stage of mathematical knowledge in order to normalize and account for students' demonstrated incoming proficiency as they enter undergraduate academics. In order to combine the SAT and ACT scores into a single standardized scale of test results, a concordance scale issued by the College Board was used to convert ACT scores to their SAT equivalents where only an ACT score was available. The mathematics portion of both tests is of more interest due to its direct relevance to calculus skills.

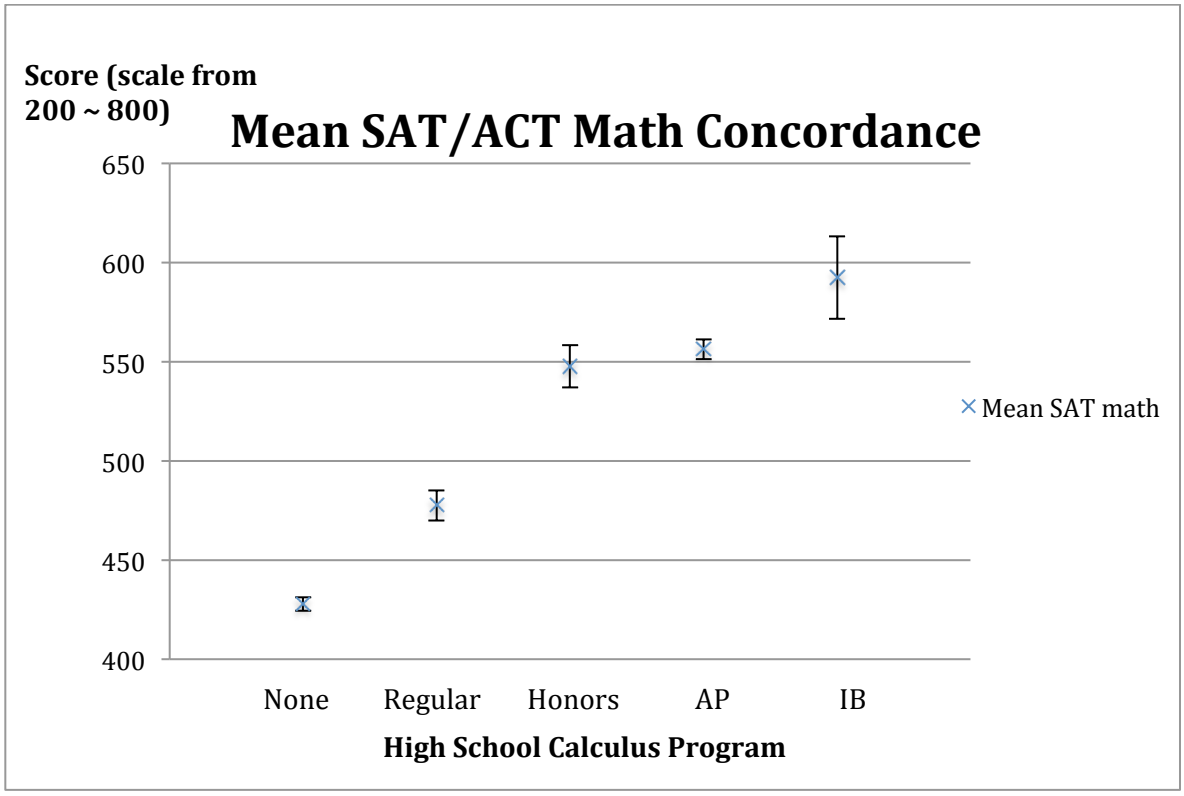


Fig. 9. Plot of mean SAT math component score by high school calculus program group.

Here, the mean values of the groups are mostly very distinct from each other, other than the honors and AP groups, which have some overlap and perform comparably. The no-calculus group is shown to have performed significantly lowest with a mean of

428 points, followed by the regular program group. Honors and AP calculus students performed comparably with mean scores of 548 and 556, respectively, while the IB mean score of 593 points was nearly 150 points higher than the mean of the first-time calculus students -- significantly higher than the rest even with its large standard error.

However, career aspiration was shown to correlate with program participation. In addition to providing a motivating factor for students who know that they will use their mathematical skills in the long run, it can be hypothesized that paths which require competitive grade point averages, such as the medical field, will motivate students to overcome such hurdles and therefore feature higher student achievement. Intended career paths were categorized as follows: medical (for those who replied "medical professional" or "health professional"), science (for "life scientist", "earth/environmental scientist", "physical scientist"), engineering (for "engineering" or "computer sciencist/IT"), mathematician, and other (including the choices of "social scientist", "businessperson", "lawyer", "English/language arts specialist", and "other non-science-related career"). A chi-squared test of independence for program and career type yielded a p-value of less than 0.0001, indicating a strongly significant relationship between those two variables. The following graph shows the career tendencies for each program group.

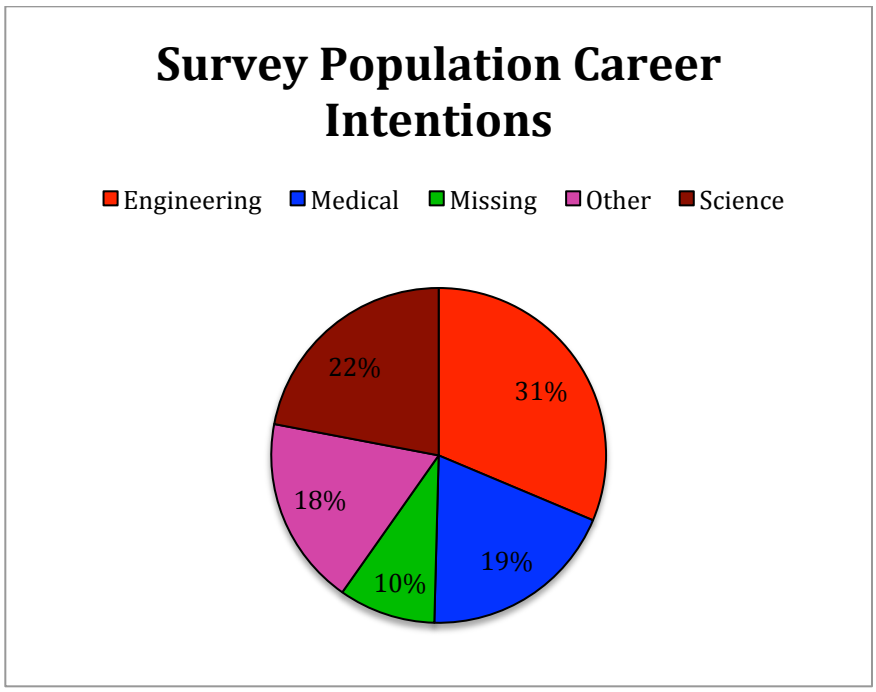


Fig. 10. Intended career paths of the survey population.

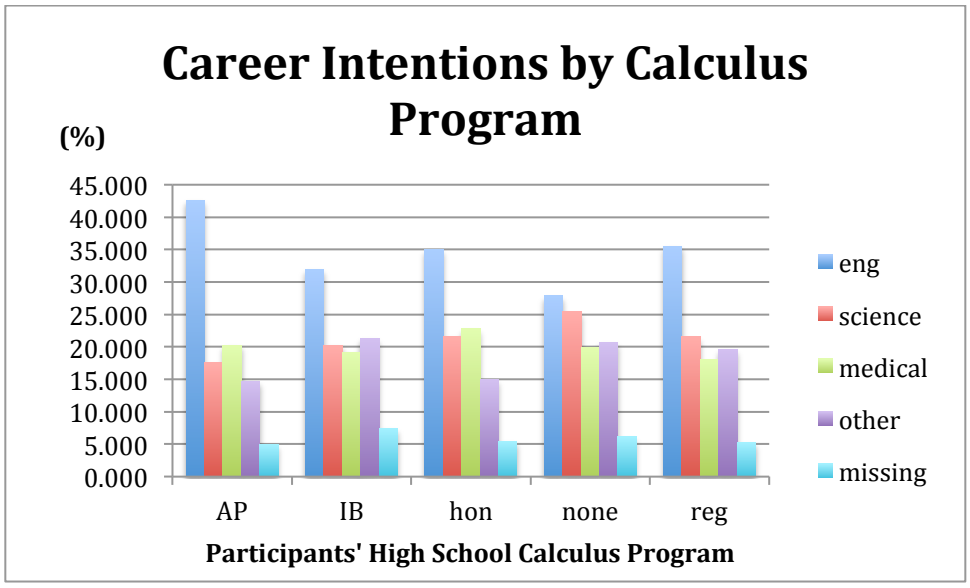


Fig. 11. Students' career aspirations, grouped by high school calculus program.

It is clear that engineering/CS is by far the most popular career category in each group, with a strikingly high proportion of AP students on that track, numbering more than twice those in the next largest group of career aspirants, who responded that they intended to

pursue a medical profession. A comparison of the patterns present in the program-specific career aspirations reveals that the first-time calculus students are the more well-rounded groups in terms of career aspirations, at least considering the career types listed here. One might assume that the differences feeding into the low p-value arise either because students seeking careers in particular fields are drawn to certain high school programs, or because the programs themselves have particular strengths or inclinations -- for example, AP might have a particularly strong engineering courses which motivated students to pursue the discipline further. In this case, we might explain the well-rounded profile of the first-time calculus students as a result of the students' lack of prior exposure to the subject. Alternatively, we might consider this profile a causal influence on their lack of experience, based on the conjecture that a large portion of them had had no incentive to take calculus in high school due to the smaller proportion of students oriented toward careers which would require calculus. A test of independence comparing the intended professional fields of the IB group against all of the other groups combined yielded a result of no dependence.

Students were also categorized in this report by their year in college. As seen above, the majority of students were in their freshman year at the time the survey was distributed, implying a tendency among students to begin their undergraduate mathematics education early on. The survey included responses up to a sixth year of college, but responses above the fourth year were eliminated in the later analysis.

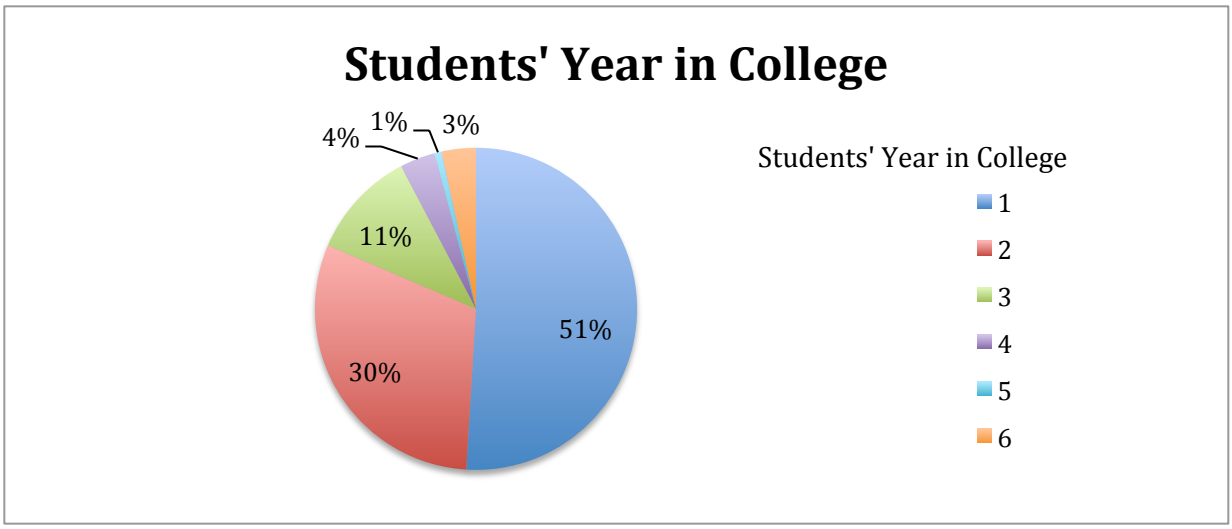


Fig. 12. Breakdown of proportions of survey population in each year of college.

We might infer that the freshman year is crucial in attracting students to STEM fields, given the stepping-stone status of calculus in many diverse disciplines and the sharp dropoff of student induction into calculus courses after the first year at university.

A chi-square test of independence yielded the result that college year and program participation were dependent, a finding that is also clear from a brief look at Fig. 13 below, which illustrates an anomalous pattern for the first-time calculus students. Although all of the students who previously took calculus in IB, honors, regular, and especially AP courses showed a marked tendency to take their first college calculus course in their freshman year, students who had had no previous calculus experience were slightly more likely to take their first course in their sophomore year. In fact, the program-specific first-year enrollment pattern (AP most prevalent, followed by IB, then honors, regular, and first-time calculus) are seen to "flip" in the data from the second-years, and the first-time calculus group have the highest calculus enrollment rate from the sophomore to the fifth year.

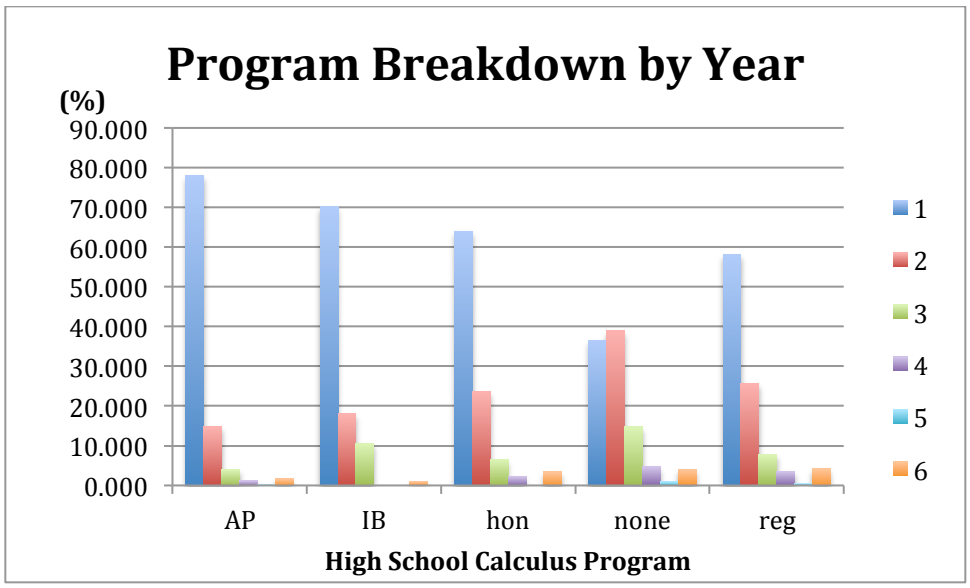


Fig. 13. Percentage of each program group in college years 1-6.

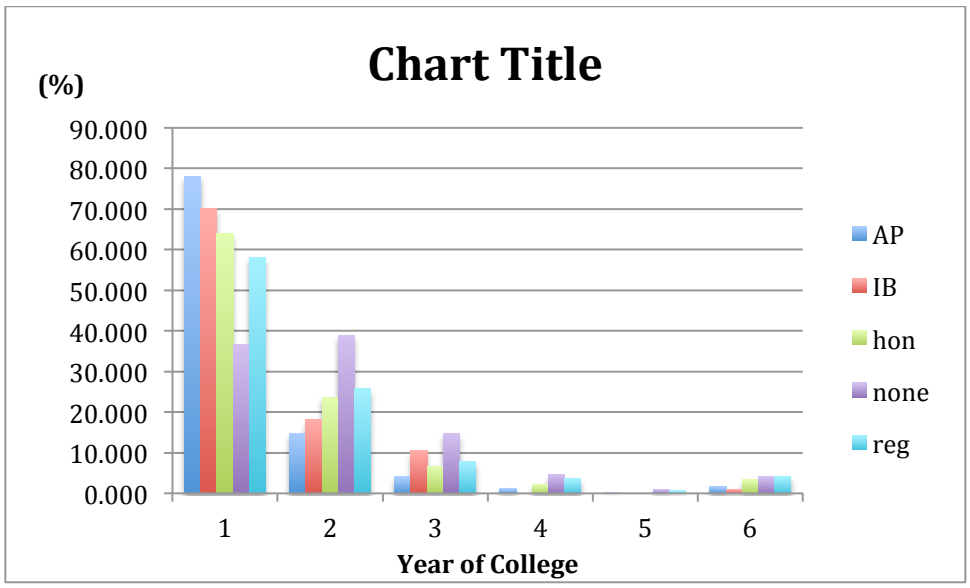


Fig. 14. Same information as in Fig. 13, organized by year.

In other words, the AP students seems to lead the general decrease in year-specific calculus enrollment with its sharp dropoff, a pattern echoed by the other students with previous calculus experience, while the first-time calculus students take more time before beginning their college calculus courses. One possible explanation is that these students are taking other math courses to compensate for their lack of previous experience and to prepare for their first calculus course. In order to test this conjecture, I examined survey

data which pertained to pre-calculus courses taken in college prior to the calculus courses in which the surveys were distributed.

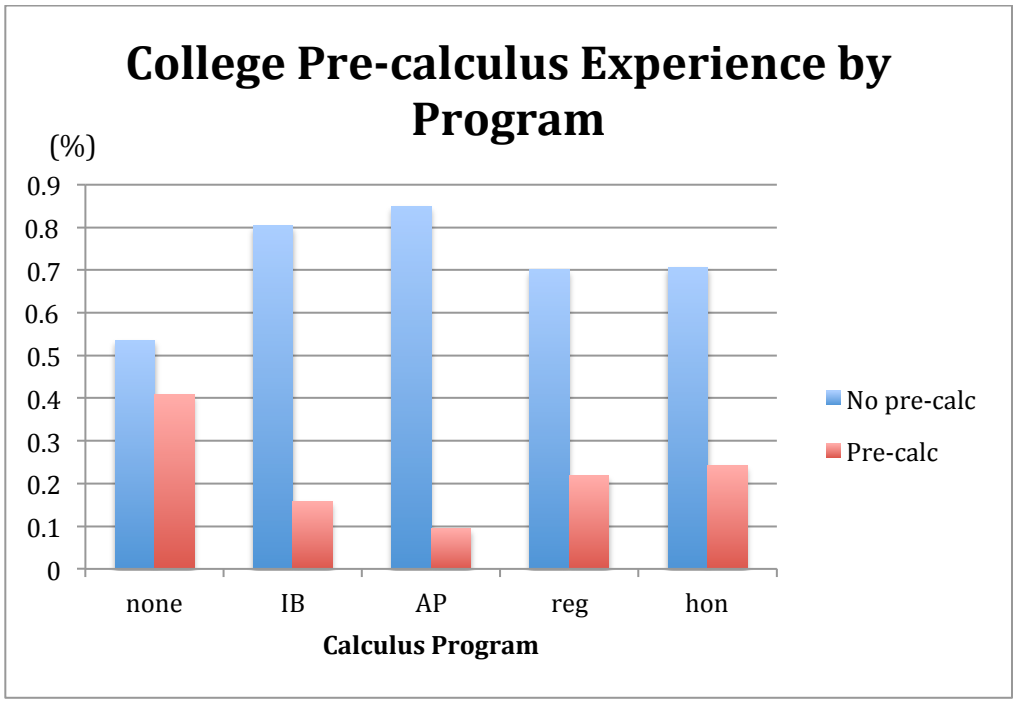


Fig. 15. Percentage of each program group who responded to having taken pre-calculus courses in college and to not having taken pre-calculus in college. Percentages of nonresponses are not shown.

With a p-value lower than 0.0001, it seems that a higher percentage of first-time calculus students are indeed taking college precalculus courses before calculus.

Several other variables were also considered out of interest regarding the continued international nature of the IB program, as well as the extent to which the pedagogical ideologies of the program actually characterize the program in practice.

The FICSMath survey sought to collect information regarding students' high school types and locations, particularly of the IB students. This aspect of the demographic was of interest due to the International Baccalaureate program's history of accommodating international students and of serving the children of people in foreign service and other mobile professions. This was a crucial step in answering the question

of how IB students are characterized. In addition, it is known that there is a slight correlation between immigration and mathematical performance in certain cases which may hold some relevance in the context of transnational immigration among IB students. Barnett, Sadler, and Sonnert (2012) studied immigrant students' performance in college math by generation and found that foreign students and the 1.25 generation (that is, those who entered the country as children) performed highest, while the 1.5 generation, who immigrated as teenagers, performed similarly to non-immigrants. In the FICSMath survey, there were three choices for information on high school location and type: students chose among "school in the US", "American school abroad", and "high school in another country". The results for the IB student subset of the survey participants, compared to the combined non-IB participant responses, were as follows:

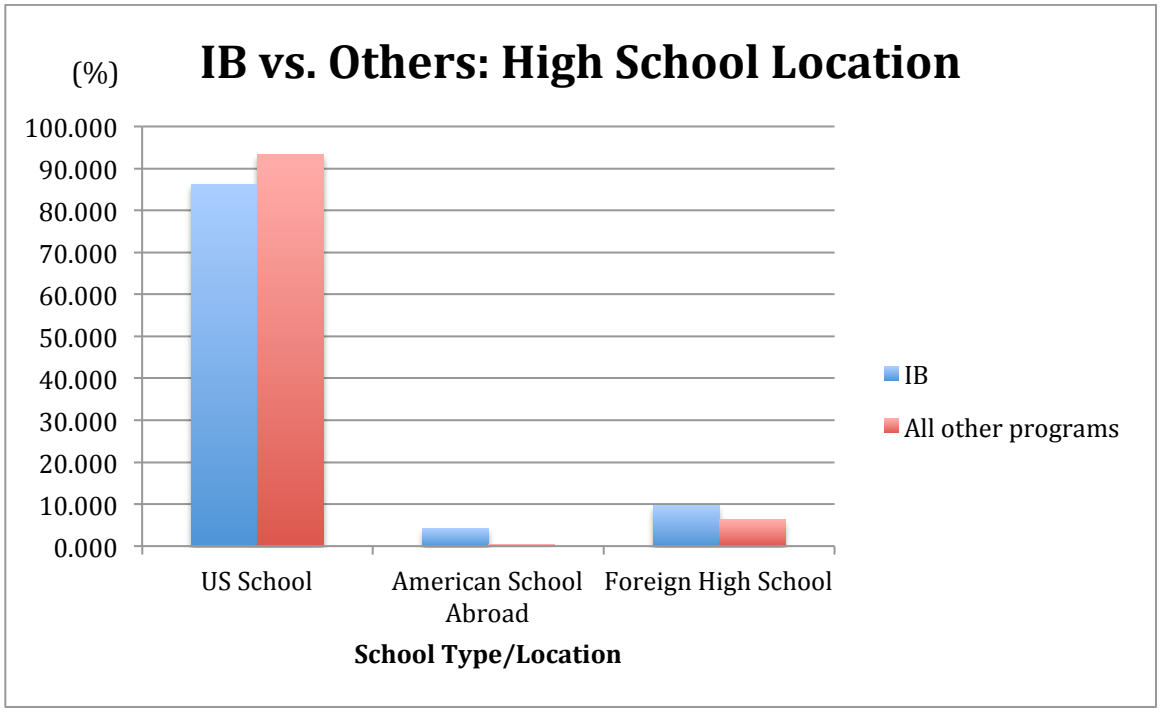
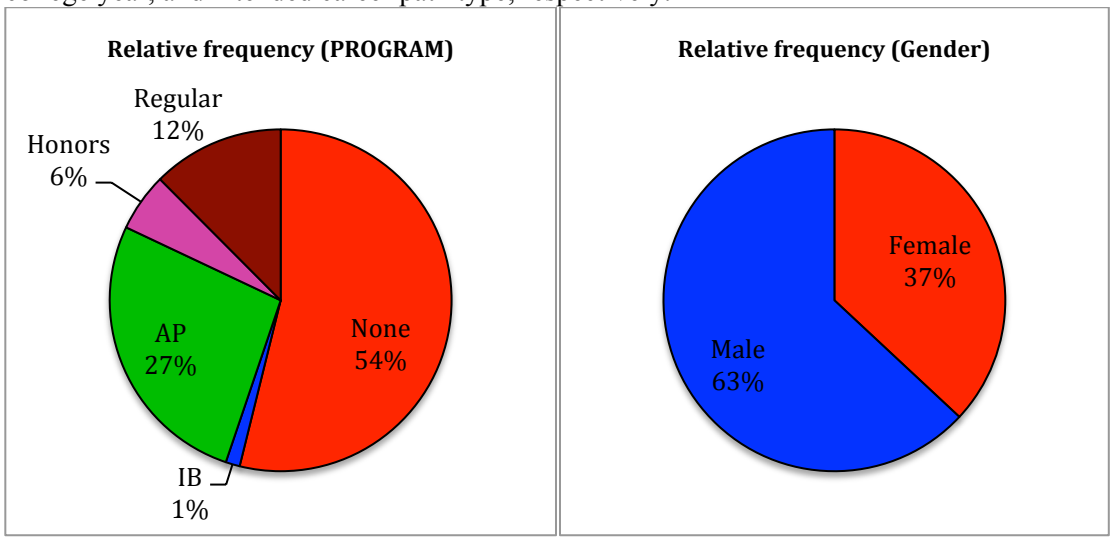


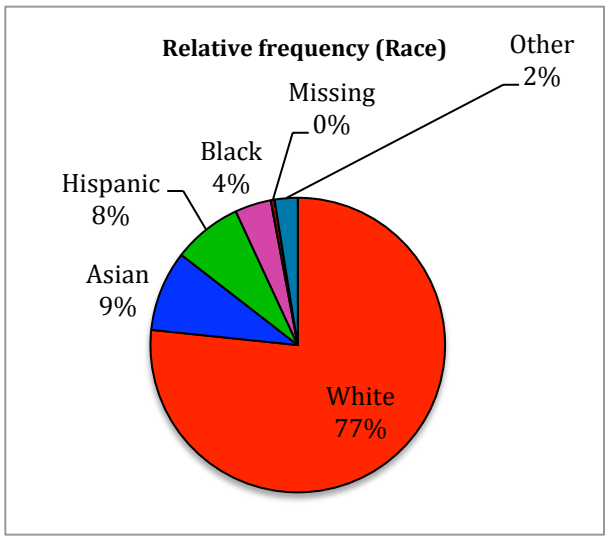
Fig. 16. Breakdown of students' high school locations for the entire survey population and IB student subset of the survey participants.

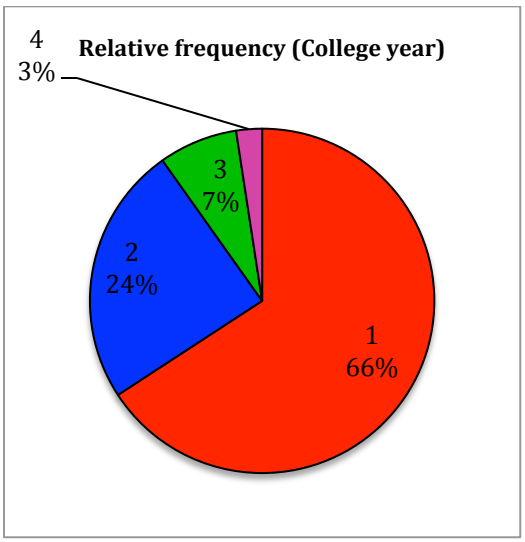
A chi-square test of significance demonstrates ($p < 0.0001$) that the proportions of IB students' responses were significantly different to those of their non-IB counterparts. This result may suggest that the International Baccalaureate is still a popular choice for the children of expatriates and other Americans abroad, or that the foreign students who come to American universities are more likely to have participated in IB. In either case, there is evidence of a higher percentage of IB graduates having spent their high school years abroad. It is unclear from this information alone whether this result speaks to the convenience of the program itself for students who have experienced international relocation, whether it results from a higher proportion of schools which offer an IB curriculum, or whether we should look elsewhere for an explanation. Nevertheless, the fact remains that the results point to a higher rate of international high school experiences among IB graduates, confirming the modern relevance of the program's original intention of accommodating students seeking education across international borders.

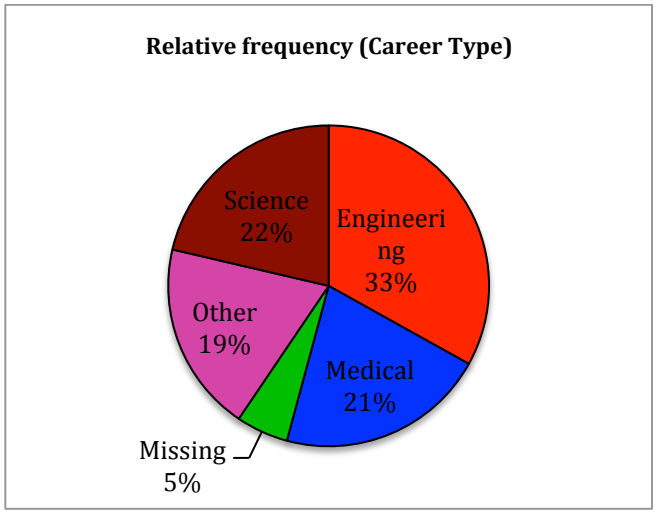
It was necessary to drop some of the participants from the data set for the purposes of the subsequent step, which involved constructing regression models for more detailed analyses. In particular, participants who had withheld responses to critical survey questions, namely those to which it was impossible to assign a nonresponse category, were automatically excluded by the program running the regression. I also chose to eliminate those who had experienced a long lapse since their most recent mathematics course and those who reported being over their fourth year of college, due to their foreseeable disadvantage, as well as the multiple program participant group, due to their extremely low number. There were also a number of students who reported having taken previous college calculus courses despite the fact that the survey was intended for distribution to first-time college calculus students. Those observations were eliminated to avoid corruption of the data. The result was a reduction to 6190 participants. The following is a brief summary of descriptive statistics after this elimination:

Figs. 17-21. New breakdown of students remaining in the analysis after eliminating critical nonresponses and atypical participants, in terms of high school calculus program, gender, race, college year, and intended career path type, respectively.









I also took the educational levels of the students' parents into account in the analysis as a demographic statistic. It was coded separately at first, with each parent being assigned a numeral denoting their highest level of schooling:

0 – Did not finish high school

1 – High school

2 – Some college

3 – Four years of college

4 – Graduate school

The average of the two parents' educational level was then taken. This was thought to be more appropriate than coding both parents separately, as it seemed likely that there would be a collinearity in which parents with higher educational levels would marry others with comparable educational backgrounds.

Students' math grades from high school were graded on a similar scale. All high school grades in mathematics courses other than calculus were coded on the standard four-point GPA scale, and the average was taken. Calculus scores were excluded in order to reduce confounding based on whether or not students had taken calculus.

The following table shows a complete view of the descriptive statistics and statistical significance of each independent variable. The columns labeled with the calculus programs list the proportions of each program group's gender and racial groups, as well as each program group's mean value in parental education, SAT/ACT math concordance score, and non-calculus math GPA from high school. The two columns to the right labeled "Overall variable p-value from Type III F-test" indicate the statistical significance of each variable, under the assumption that all other variables in the model are present. The first of these columns displays the p-value result of the Type III F-test with all of the calculus programs categorized separately. The F-test in the second column compares IB to all other programs combined, to compare the program isolated against all non-IB students. The F-test result for categorical variables is derived from a chi-square test of independence, and the result for continuous variables comes from an ANOVA (analysis of variance) model. The stars listed in the p-value columns indicate statistically significant values – that is, a result in which the corresponding independent variable is significant.

		High school calculus program				
Independent variables						
		None	IB	AP	Honors	Regular
Demographics	**Gender (%)**					
	Female	37.8	32.5	35.4	38.1	36.7
	Male	62.2	67.5	64.6	61.9	63.3
	Race (%)					
	White	72.0	61.4	77.3	75.7	81.9
	Asian	8.73	14.5	8.31	10.6	7.4
	Hisp	8.76	8.43	6.87	4.99	3.8
	Black	4.47	9.64	2.83	4.40	2.6
	Other	3.51	0.00	2.11	2.05	2.5
	Missing	2.49	6.02	2.53	2.35	1.9
	Parental Education (mean)	2.34	2.63	2.57	2.68	2.55
Academic prep	**ACT_SAT_m (mean)**	586.7	655.7	649.0	643.5	627.5
	Math GPA HS (mean)	3.36	3.66	3.63	3.60	3.59

Table 1. Descriptive statistics by program: gender and racial proportions of each program group, along with mean values of parental education level, ACT-SAT concordance scores, and high school math GPA.

		Overall variable p-value from type III F-test	
Independent variables			
		With all programs distinct	IB vs. other programs
Demographics	**Gender (%)**		
	Female	0.442	0.400
	Male	0.442	0.400
	Race (%)		
	White	***	**
	Asian	0.138	0.057
	Hisp	***	0.721
	Black	***	**
	Other	*	0.551
	Missing	0.259	0.642
	Parental Education (mean)	***	0.089
Academic prep	**ACT_SAT_m (mean)**	***	***
	Math GPA HS (mean)	***	*

Table 2. Significance of independent variables. The p-values in this chart are coded with stars denoting the significant p-values in order of increasing significance level.
* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

The program participation rates, when specified by race, reveal some interesting trends, particularly in the racial proportions within the IB group. The proportion of IB Caucasian students is considerably lower than the proportions of Caucasian students in other groups. Conversely, the proportion of Asian students is much higher in IB, at 14%, than in other groups, where they tend to comprise 7 to 10 percent. Black students are

also heavily represented in IB relative to other calculus groups: whereas they form up to five percent of the other groups, ten percent of the IB population is Black.

It appears from the F-test results that though nearly all of the independent variables have significant effects with the exception of gender in the model with all of the calculus programs kept as distinct categories, the significance of those variables diminishes when the IB and non-IB distinction becomes the focus of the program categorization. In particular, the Black and White racial groups remain significant in the analysis specifically comparing IB and non-IB groups, as well as the ACT-SAT concordance scores and high school math GPA, while the parental education level loses significance.

C. Research Question Two

A multiple regression analysis was carried out with the college calculus grade as the dependent variable and with program affiliation, gender, race, college year, intended career path, and college teacher as the dependent variables. Choice of career path were categorized here as science, engineering, medicine, non-STEM fields, as well as a combined non-response and multi-response group, as the survey did not distinguish between nonresponses and multiple responses. Intended career paths were expected to be significant because of the pressures to achieve high grades in order to pursue certain disciplines. With $R^2 = 0.341$ and adjusted $R^2 = 0.300$, the results are as follows:

		Coefficient	Std err	P-value
Independent variables				
Variable of interest	**HS calculus group**			
	None	0.00	0.00	
	IB	4.52	1.38	**
	AP	5.18	0.41	***
	Honors	4.52	0.72	***
	Regular	3.59	0.51	***
Demographics	**Gender**			
	Female	0.00	0.00	
	Male	-1.87	0.36	***
	Race			
	White	0.00	0.00	
	Asian	1.34	0.65	*
	Black	-1.62	0.87	0.06
	Hisp	-1.23	0.67	0.07
	Other	0.01	2.62	0.99
	Missing	-0.36	0.75	0.63
	Parental education	0.72	0.17	***
Academic prep	**ACT/SAT_m**	0.03	0.00	***
	Math GPA HS	7.27	0.34	***
College characteristics	**College year**			
	1	0.00	0.00	
	2	-1.65	0.44	***
	3	-0.25	0.68	0.71
	4	-0.09	1.09	0.94
	Career plan			
	Other	0.00	0.00	
	Engineering	1.70	0.55	**
	Medical	1.56	0.55	**
	Science	1.48	0.54	**
	Missing	-1.33	0.80	0.10

Table 2. Regression model results – includes all main effects variables. The p-values in this chart are coded with stars denoting the significant p-values in order of increasing significance level. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Here, the coefficients represent the relative course grades associated with each independent variable. Thus, the according to the values derived from the chart, with the first-time calculus students' grades held as the baseline, the IB group's grades are 4.54 points higher, the AP group's grades 5.2 points higher, and so on. The associated p-

values are the result of a test on the hypothesis that the coefficient equals zero; if the p-value is less than 0.05, the hypothesis is rejected and we consider the variable to be a significant effect in the model. Thus, from the above table, the baseline group's course grade is significantly different from every other participant group's grades. The continuous independent variables work in a similar way: each additional math GPA point in high school is associated with a 7.3 point increase in the college calculus course grade, and this is a significant effect as indicated by the p-value. I also ran this same procedure using the IB group as the baseline instead. This yielded the result that apart from the group with no prior calculus experience, no other calculus program groups' coefficients were significantly different from the baseline. The only pair of calculus program groups which had any significant difference in coefficients was the AP and regular groups, with a difference of 1.6 points and a p-value of 0.004. Thus, we conclude that the specific type of calculus course taken in high school for the most part does not have a statistically significant effect on the first college calculus course grade, with the exception of the AP and regular calculus groups, where AP had the advantage. Where IB is concerned, however, there is no significant difference between IB students' performance and the performance of other students who had previously taken calculus. It is only the lack of prior calculus experience which results in any significant difference in students' degree of preparation for college calculus.

Figure 7 in this report showed each program group's mean final grade. The following is a graph of the program-based coefficients superimposed on the previous raw results. The raw mean information has been modified only by plotting relative grades –

that is, difference of each group's grade means and mean grade of group who had no calculus in high school.

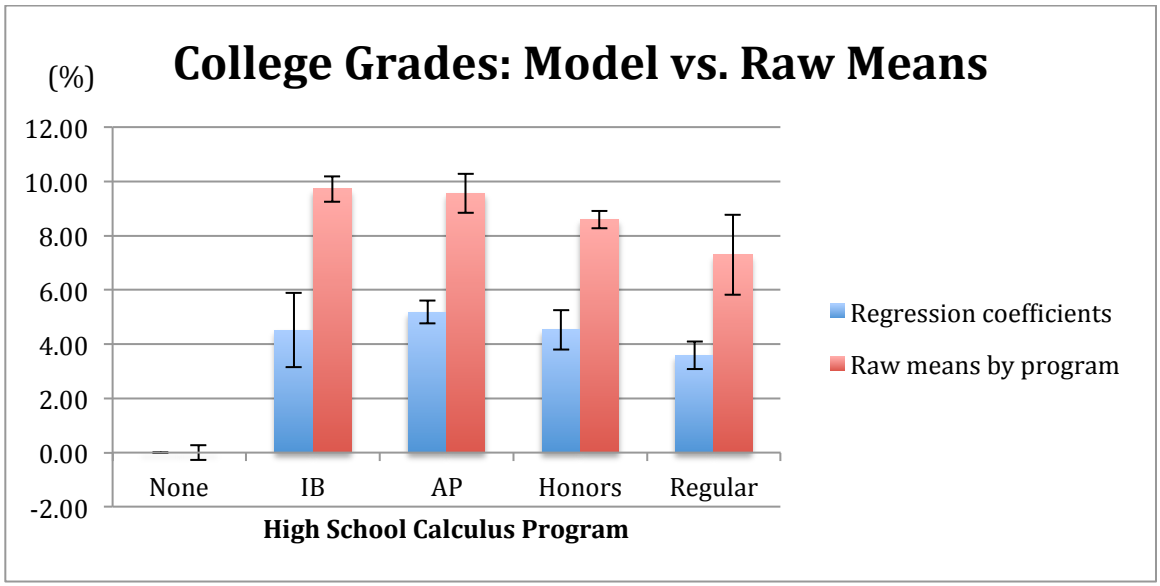


Fig. 22. Side-by-side graph of the relative grades of each calculus program group in their first college calculus course, for comparison between coefficients obtained in the regression model and the raw mean grades. Both the raw means and model coefficients use the "none" group as the baseline.

This plot demonstrates that the model results and the raw data are consistent in the general pattern of relative grades. They do not completely coincide because the regression took other factors into account in addition to program affiliation.

Two more points are notable in the regression model: the coefficients include a significant dip in grades in the second year of college. The sophomores' grades are lower by 1.66 points compared to the freshmen's, and the juniors and seniors' grades later rise to a level comparable to that of the freshman group. We might attribute this to the phenomenon commonly known as "sophomore slump", in which some of the pressure which marked incoming students' first years has diminished somewhat, possibly explaining the dip in grades. Finally, it is interesting to note the relatively low grades of the students for whom information on career paths was "missing": their associated grades

are 1.3 points lower than the baseline, “other careers”, and 3 points lower than the students who indicated that they intended to become engineers. Since this question did not allow multiple answers, this group included nonresponses as well as students who reported multiple answers. There was no “undecided” career option. Though I did not have the information required to parse out these alternatives, two explanations are possible. First, if we assume that nonresponses dominated this question over responses with multiple choices, and that nonresponses were due to students being undecided regarding their future paths, one possible interpretation is that simply having a career aspiration in itself is helpful in boosting students’ grades, through direct or indirect means. A different but related possibility concerns students who indicated multiple career paths under consideration; perhaps students who have more career aspirations than one are at a disadvantage due to a lack of focus and commitment to any single career path.

Finally, one more model was considered. All of the variables from the previous model were included, but this time interaction terms were included as well. Interaction terms are meant to control for differences in the effects of individual independent variables depending on combination with other independent variables. For example, the contribution to a student’s calculus grade after having participated in Advanced Placement in high school might depend on the gender of the student, or there could be a differential effect of each GPA point on the various calculus programs. In such cases, the model needs to include an interaction term in the model, coded as the product of the two variables under consideration: thus, in the examples mentioned, one would use *Program*Gender* and *Program*GPA*, respectively. The model includes every paired

combination of main effects variables in creating such terms, and treats them like every other variable in assigning them a coefficient and statistical significance level. Afterwards, the statistically insignificant interaction terms are eliminated iteratively based on the p-values derived from F-tests, until the remaining model includes only main effects variables and statistically significant interaction terms.

At the end of this process, all interaction terms had dropped out of the model, and only the main effects variables remained in the model. This result should be interpreted as an indicator that there are no significant interaction effects in this model and that each dependent variable coefficient is the same regardless of other factors. High school math GPA has no bearing on the relative college grades associated with each high school calculus program, gender has no differential effect based on whether a student took calculus in high school, and so on.

IV. Conclusion

There are some limitations of this paper which could perhaps be addressed in future research. First, it can only provide data on the subset of each program with an interest in STEM fields or specifically in calculus. It would be useful to look at similar data from students taking other subjects in order to obtain a bigger-picture profile of their interests, background, and abilities in general. There is also little research to date using transnational data; obtaining and analyzing such information would also help to separate the effects of certain additional variables which may be affecting the analysis presented in this paper, as well as to examine whether the efficacy of an IB education differs in various school systems.

Furthermore, in addition to looking at the direct empirical data as I have done, a huge improvement on the current literature would be to introduce questions of causality in the issues discussed here, especially if we want to make decisions regarding the future of these programs. That is, do students of different demographic and academic backgrounds prefer different programs and paths because of their experiences, or is it the programs themselves which shape their tendencies in society and academics? To what extent do inter-group differences feed into each other, and how can we ensure that every student has equal access to programs of their choice and to learning opportunities that would benefit them? The far-flung ramifications of such questions could lead to some large-scale and important changes.

The main goals of this report were to examine the demographic of the International Baccalaureate student population and to examine how it fared in preparing students for college calculus compared to other high school calculus programs. To

achieve the first goal, I compared the students of each group by their demographic data and levels of prior academic preparation at the time they were taking the course and found that IB students have a higher rate of foreign high school attendance than non-IB students and that they tend to live in relatively high-income regions. The regression analysis revealed significant main effects variables due to demographics and academic preparation. These results included the finding that career aspirations are significantly related to college calculus performance: the engineering group performed the best, while students who indicated no intended career path did significantly worse than all the other groups, perhaps indicating that the simple existence of a career aspiration is a powerful motivator and beneficial in itself. The most important result of this thesis, however, is that IB students performed comparably to the AP, honors, and regular calculus takers, while their scores were significantly higher than the students who had never taken calculus in high school. Although there was a significant difference in the performance of AP and honors groups, excluding this exception, the results can be generalized as showing only two main groups defined by whether students had previously taken calculus in high school or not. Those who had had no calculus experience did the worst in their first college calculus course, while previous exposure to calculus was a substantial factor which benefitted students' performance in college calculus.

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