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International Baccalaureate Mathematics, Advanced Placement Mathematics, and Dual Credit Mathematics Courses – An In Depth Look

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Abstract

Every year in the United States, many students who believe they are fully prepared for college find out that they have to take remedial math courses before they can take any credit bearing math courses toward their degree. A student can avoid this situation by taking an early college program in high school and potentially earning a college math credit. The purpose of this research project was to take an in depth look at three such programs. The names of these programs are the International Baccalaureate program, the Advanced Placement program, and Dual Credit programs. This research project looked into the histories of these programs, what is being taught in the mathematics classes of these programs, and what research says about these programs.

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Introduction

In the July 2010 College Board AP conference, then secretary of Education Arne Duncan said the following:

> The mission of high schools can no longer be to simply get students to graduate. Their expanded mission must be to ready students for careers and college without the need for remediation. High schools must shift from being last-stop destinations for students on their education journey to being launching pads for further growth and lifelong learning. (Duncan, 2010)

In that same speech, Mr. Duncan went on to explain that our secondary schools were designed to reflect life in the 1940's, when only one in 16 young adults enrolled in colleges and universities. He also went on to explain that about a quarter of students today drop out of high school, and college entrance exams suggest that only about 25% of graduating high school seniors in America are college ready. Furthermore, he said, in community colleges, more than 40% of all students take at least one remedial class. He summed up his thoughts by saying, "The entire culture of high schools must be changed to support student success beyond K-12" (Duncan, 2010).

Why did Mr. Duncan speak so passionately about a need to change the culture of our high schools? One reason might be how the senior year of high school is viewed in America. In a bulletin put out by the National Association of Secondary School Principals titled, *Rethinking the Senior Year*, Conley commented that many students view the senior year of high school as a reward for participating in 12 years of schooling. And as students turn 18 and are recognized as an adult by the law, they must still abide by school rules that treat them the same as their 15 year

old counterparts (Conley, 2001, p. 26). In the same bulletin Conley further explains that even the most committed college bound students often view senior year as a "blow-off" because they have already been accepted into college and have met graduation requirements (p. 27). This makes logical sense. If a student has already been accepted into the college in which they wish to attend, and they have already met most of the graduation requirements for high school, then the student may not be very motivated to work hard during their senior year.

This sentiment was echoed by another study done by Michael W. Kirst of Stanford University. Kirst commented that many high achieving students have little motivation to use their senior year to become academically prepared for college. He noted that, "The high school suffers from less academic effort by the best academic students, and the universities lose a headstart such students could make upon their undergraduate general education requirements" (Kirst, 2000, p. 2). Kirst then went on to note that there was one class in particular many high school seniors were not taking that was causing major problems on their college placement exams. That class was a mathematics class. Kirst then commented that a whopping 68% of students admitted to California State Universities must take at least one remedial mathematics course (Kirst, 2000, p. 2). Furthermore, as noted by Kremers (2010), a 2004 national study showed that over 82% of high school seniors stated they were planning to attend either a four-year college or a community college. And out of those students who were planning on earning a bachelor's degree, only one-third could solve mathematics problems involving intermediate-level mathematics skills, thus revealing a disconnect between the student's aspirations and their preparedness. Kremers (2010) goes on to further state that:

> The transition gap between secondary and post-secondary education in mathematics is a complex phenomenon covering a vast array of problems and issues. Although there is

> evidence of similar ‘gaps’ in other disciplines in science and beyond, it seems that the transition in mathematics is by far the most serious and the most problematic (p. 22-3).

The question that then needs to be addressed is: What can secondary school administrators and teachers do to help students bridge this mathematics ‘transition gap’ from high school to college? The answer to that question may be to offer high school seniors a chance to earn a college math credit during their senior year by taking a challenging “college level” mathematics class while still in high school. The main purpose of this study will be to research three programs that offer high school students a chance to earn a college mathematics credit by taking a course at their high school. These three programs are called: International Baccalaureate, Advanced Placement, and Dual Credit.

International Baccalaureate Program

History of the IB Program

The International Baccalaureate (IB) is a non-profit organization that was founded in 1968 in Geneva, Switzerland. The IB has offices across the world and works with over 4000 schools to offer challenging courses to students aged 3 to 19 (Bergeron, 2015). The IB organization currently offers four different programs that schools around the world can apply to use. The "Primary Years Programme" is for students aged 3 – 12. The "Middle Years Programme" is for students aged 11 – 16. The "Career-related Programme" is for students aged 16 – 19 who are primarily looking for an apprenticeship or employment directly out of high school (*Programmes*, 2017). The "Diploma Programme" was designed for students aged 16 – 19, and the IB organization describes it as providing a strong pathway for students to either enter universities or employment upon completion (*Diploma Programme*, 2017). The Diploma Programme is the program that the IB organization began in 1968, and is the one IB program that will be analyzed in this research paper. The other three programs are each less than 25 years old (*Programmes*, 2017).

The IB Diploma Programme was initiated by educators in international schools who were constantly faced with multiple different entrance exams required by the nations where their students were considering post-secondary education (Callahan, 2003). In the 1960's, secondary school educators were not happy that, depending on where their students wanted pursue their post-secondary education, they had to take different entrance exams. These educators determined that if they could create an international curriculum at the secondary level, then different colleges and universities in various countries could all recognize that common curriculum, in turn alleviating the need for students to take numerous different entrance exams.

The International Baccalaureate's early literature stated that the program was designed to meet the needs of highly motivated and academically gifted secondary students. Although later literature from IB dropped the words "academically gifted", and more simply stated that the program targeted highly motivated students aged 16 - 19 (as cited in Callahan, 2003, p. 4).

The IB Diploma Programme found its way into United States schools for the first time in 1971, and has been growing in use ever since. Currently there are 910 schools in the United States that offer the IB Diploma Programme (*United States*, 2017).

Goals and structure of the IB Diploma Program

The stated mission of the IB is to "develop inquiring, knowledgeable, and caring young people who help to create a better and more peaceful world through intercultural understanding and respect" (*The IB: An Historical Perspective*, 2015). The organization further goes on to explain that they want IB learners to strive to be: Inquirers, Knowledgeable, Thinkers, Communicators, Principled, Open-Minded, Caring, Risk-Takers, Balanced, and Reflective (*What is an IB education*, 2013). They also stated that an IB education is holistic in nature, and is concerned with the whole person. "Through the interplay of asking, doing, and thinking, this constructivist approach leads towards open, democratic classrooms. An IB education empowers young people for a lifetime of learning, independently and in collaboration with others" (*What is an IB education*, 2013, p.4).

Examining how the IB organization described an IB education, it should come as no surprise that if a high school student chooses to enroll in the IB program, they simply cannot enroll in one IB class. For example, if a student excels at mathematics and wishes to take an IB mathematics course, they cannot only enroll in the IB mathematics course. Student seeking the IB diploma must select one subject from each of five different groups. Those five groups are: 1 –

Language A1 (first language of the student), 2 – Second Language, 3 – Individuals and Societies, 4 – Experimental Sciences, and 5 – Mathematics. In addition each student must select a sixth class from either an "Arts" group, or another course from one of the first five groups (*International Baccalaureate Diploma Programme Subject Brief – Mathematical Studies SL*, 2014).

The IB mathematics program today

There are four different mathematics courses in which IB students can enroll in. They are: Mathematical Studies Standard Level (SL), Mathematics SL, Mathematics Higher Level (HL), and Further Mathematics HL. (Details on each of these four courses will follow.) Each course is designed to fit the different needs and ability levels of students, in addition to fulfilling each student's different post-secondary and career aspirations (Bergeron, 2015). There are certain goals that the IB organization wishes each of its mathematics courses to accomplish. Many of these goals are listed below. The IB wants to enable students to:

- Enjoy mathematics, and develop an appreciation of the elegance and power of mathematics;
- Develop an understanding of the principals and nature of mathematics;
- Develop logical, critical, and creative thinking;
- Develop patience and persistence in problem solving;
- Apply and transfer skills to alternate situations, and to other areas of knowledge; and
- Appreciate the international dimension in mathematics through an awareness of the universality of mathematics and its multicultural and historical perspectives (Bergeron, 2015, p. 8-9).

At the end of each course, students earn a grade on a scale of 1 through 7. (With 1 being the lowest and 7 being the highest grade). For Mathematical Studies SL, Mathematics SL, and for Mathematics HL, 80% of the scaled grade comes from a final examination taken at the end of the course, while 20% of the grade comes from an internal assessment (usually a paper) that is graded by the teacher of the course. For students taking Further Mathematics HL, their grade is entirely based on a final examination score (Bergeron, 2015). It is these final scaled grades that colleges and universities will look at when determining whether to grant incoming students any college credit. Although almost every single college and university throughout the United States has different credit granting policies when it comes to awarding incoming students credit for IB mathematics, there are a couple of trends that most colleges and universities seem to follow. The first trend is that most colleges and universities only reward college credit for students who have taken Mathematics HL or Further Mathematics HL. Not many colleges and universities grant credit to students for taking Mathematical Studies SL or Mathematics SL. The second trend is that many colleges and universities will grant credit for a score of 5 or higher in the mathematics HL course. However, some selective colleges may demand a score of 6 or even a score of 7 to earn any credit at their institution (Worthington Schools District, 2012).

The IB Mathematics course that would be considered to have the lowest level of mathematical rigor is Mathematical Studies SL (standard level). The most recent figures provided by the IB organization indicated that in 2016, approximately 36.6% of all IB students were enrolled in this course (*The IB Diploma Programme Statistical Bulletin*, 2016). The Mathematical Studies SL course syllabus focuses on: “placing more emphasis on student understanding of fundamental concepts than on symbolic manipulation and complex manipulative skills; giving greater emphasis to developing students’ mathematical reasoning

rather than performing routine operations; solving mathematical problems embedded in a wide range of contexts; using the calculator effectively" (*International Baccalaureate Diploma Programme Subject Brief – Mathematical Studies SL,* 2014, p. 1). The seven main topics of Mathematical Studies SL are: numbers and algebra, descriptive statistics, logic, sets and probabilities, statistical application, geometry and trigonometry, mathematical models, and introduction to calculus (*International Baccalaureate Diploma Programme Subject Brief – Mathematical Studies SL,* 2014). Additionally, the IB organization states that, "students taking this course are well prepared for a career in social sciences, humanities, languages, or arts" (*Mathematics SL Guide,* 2014, p. 5).

The IB mathematics course that would be considered the "next level up" in mathematical rigor from Mathematical Studies SL, would be Mathematics SL. Mathematics SL is the IB mathematics class that has the highest number of students enrolled worldwide. As of 2016, 49% of IB students were enrolled in Mathematics SL (*The IB Diploma Programme Statistical Bulletin,* 2016). The IB organization stated that the intention of Mathematics SL is to introduce students to mathematical concepts "in a comprehensive and coherent way, rather than insisting on the mathematical rigor required for Mathematics HL" (*International Baccalaureate Diploma Programme Subject Brief – Mathematics SL,* 2014). The six main topics of Mathematics SL are: algebra, functions and equations, circular functions and trigonometry, vectors, statistics and probability, and calculus (*International Baccalaureate Diploma Programme Subject Brief – Mathematics SL,* 2014). The IB organization stated that the majority of students taking Mathematics SL "will expect to need a sound mathematical background as they prepare for future studies in subjects such as chemistry, economics, psychology, and business administration" (*Mathematics SL Guide,* 2014).

The IB mathematics course presenting an even higher level of mathematical rigor is aptly named Mathematics Higher Level (HL). As of 2016, 14.2% of IB students were enrolled in Mathematics HL (*The IB Diploma Programme Statistical Bulletin,* 2016). The course description of Mathematics HL stated that the course "focuses on developing important mathematical concepts in a comprehensible, coherent and rigorous way, achieved by a carefully balanced approach" (*International Baccalaureate Diploma Programme Subject Brief – Mathematics HL,* 2014, p. 1). It is interesting to note that this is the first course description that mentioned mathematical proofs. In the course description it also explicitly stated, "Development of each topic should feature justification and proofs of results" (*International Baccalaureate Diploma Programme Subject Brief – Mathematics HL,* 2014, p. 1). The six main topics of study for Mathematics HL are the same as they were for Mathematics SL, however each topic (except for functions and equations) the teacher is expected to spend more hours teaching. In addition to studying those same six topics, Mathematics HL also requires students to study one of the following four topics in much greater detail: statistics and probability, sets, relations and groups, calculus, and discrete mathematics (*International Baccalaureate Diploma Programme Subject Brief – Mathematics HL*, 2014). One other significant difference between the Mathematics HL and the two SL classes is that with the SL classes teachers are recommended, by the IB organization, to spend 150 teaching hours to cover the curriculum. In comparison, with the Mathematics HL classes, teachers are recommended to spend 240 hours teaching the curriculum (*International Baccalaureate Diploma Programme Subject Brief – Mathematics HL,* 2014). Lastly, the IB organization stated that the majority of students taking Mathematics HL "will expect to study mathematics at (a) university, either as a subject in its own right or as a major component of a related subject" (*Mathematics SL Guide*, 2014, p. 5).

The last mathematics course offered by IB is called Further Mathematics HL and it contains the highest amount of mathematical rigor. However, there are few students throughout the world who take this course. In 2016, only 176 students, or 0.2% of all IB students took this course (*The IB Diploma Programme Statistical Bulletin*, 2016). The course description for Further Mathematics HL stated that the course caters to "students with a very strong background in mathematics who have attained a high degree of competence in a range of analytical and technical skills, and who display considerable interest in the subject" (*International Baccalaureate Diploma Programme Subject Brief – Further Mathematics HL*, 2014, p. 5). The six main topics of study for Further Mathematics HL are: linear algebra, geometry, statistics and probability, sets, relations and groups, calculus, and discrete mathematics. Like Mathematics HL, Further Mathematics HL also recommends 240 teaching hours for the entire course (*International Baccalaureate Diploma Programme Subject Brief – Further Mathematics HL*, 2014). In describing the type of student the IB organization envisions taking Further Mathematics HL, they use the same descriptors they used with Mathematics HL. Namely, they envision a student who plans to study fields such as mathematics, engineering, or technology in a post-secondary institution taking Further Mathematics HL (*Mathematics SL Guide*, 2014).

What does research on the IB mathematics program say?

Independent research on the impacts of the IB program have been very limited (Callahan, 2003). This is especially true in regards to the IB mathematics program. However, there has been at least one independent study that attempted to see if there was any correlation between students taking an IB mathematics course and their standardized test scores.

In 2011 Meister (2011) did a study that attempted to find a relationship between participation in the IB Mathematical Studies SL course and performance on a high stakes test.

This particular study involved students who all attended one particular high school in northern Kentucky. All of the students in the study had completed Algebra 1, Algebra 2, and Geometry by the beginning of their junior year, and then had chosen to enroll in either IB Mathematical Studies SL or a pre-calculus course. The researcher used the students 10th grade PLAN test scores, along with a few other factors to match up 31 pairs of students to study. (31 students in IB mathematics SL paired with 31 students in pre-calculus). The researcher found that the 31 students who took IB Mathematics SL had an average score of 31.7 on the mathematics portion of the Kentucky Core Content Test (KCCT). Meanwhile, the 31 students who took the pre-calculus course averaged 19.3 on the mathematics portion of the KCCT. The IB students scored an average of 12.4 points higher or a staggering 64% better than their pre-calculus counterparts. Because the results were so dramatic, the researcher decided to also compare the students' ACT mathematics scores. (For this part of the study, only 16 pairs of students from the original study also took the ACT mathematics test, so only 16 pairs of students' scores were analyzed.) The 16 students who had taken IB Mathematics SL scored an average of 20.2 on the ACT mathematics test, while the 16 students who had taken the pre-calculus course averaged 17.6 on the ACT mathematics test. This time the IB students averaged 2.6 points higher or approximately 15% better than their pre-calculus counterparts. Obviously, there are many limitations to this study including but not limited to: the extremely small sample size, student motivation, and teacher effectiveness. One other point the researcher mentioned was that the students in the IB Mathematics SL course spent a significant amount of time throughout the year using graphing calculators, implying that the students in the pre-calculus course did not spend nearly the same amount of time using a graphing calculator (Meister, 2011). Despite the limitations of the study,

the results should not simply be ignored. Rather, these results could serve well as a point of reference for another study in the future.

Conclusions about the IB mathematics program

Based on data available from the IB organization and from the National Center for Education Statistics (NCES), only approximately 3.4% of secondary schools in the Unites States offer the IB curriculum (The International Baccalaureate Organization, *United States*; NCES, *Table 105.50 Number of educational institutions*). Despite this seemingly small number, there are many students in the United States who do happen to attend schools that offer IB classes, and who will have to make a decision on whether or not to enroll in IB classes. Looking at it from the perspective of the IB mathematics classes offered, if a student's goal is to gain college credit for taking a mathematics class in high school, then the student would definitely want to make sure that his or her school offered IB mathematics at the HL level. (As stated earlier, there are not many colleges and universities in the United States that offer college credit for IB mathematics classes taken at the SL level.) Even if the secondary school in question does offer IB mathematics at the HL level, the student would still be encouraged to research each post-secondary institution in which he or she plans to apply, in order to see what their specific credit granting policies for IB mathematics are.

Advanced Placement Program

History of the AP program

In 1951, faculty at Kenyon College had discussions about giving strong secondary school students an opportunity to begin working toward a liberal arts degree before officially enrolling in college. The idea gained momentum, and soon a committee formed with representatives from 12 United States colleges and universities as well as 12 representatives from secondary schools. At the time the committee was forming, a report put out by the Harvard University Press in 1952 identified one main weakness in the United States educational system. That weakness they identified was, “a failure of (secondary) schools and colleges to view their jobs as parts of a continuous process” (Diyanni, 2008, p.1). (The introduction of this paper presented evidence that this weakness still exists to this day!) The most influential conclusion to be drawn from this report was that secondary school students should be allowed to take college-level courses at their schools during their senior year. Then, during the 1953-54 academic year, the committee, along with the Educational Testing Service (ETS) developed and administered examinations to high school seniors at the participating secondary schools, and freshmen at the participating post-secondary institutions. With the help of this comparability study, the committee then allowed The College Board to officially take over the Advanced Placement (AP) program and in May 1956 the first official AP examinations were taken (DiYanni, 2008). That very first year, 104 secondary schools participated in the AP program with 1,229 students taking 2,199 AP exams (*Annual AP Program Participation*, 2015).

Through the years, the AP program has continued to grow. According to data put out by the College Board, the amount of schools participating in the AP program, the number of students taking AP examinations, and the total number of examinations taken has continually

grown every single school year save 1972-73. The most recent data available from The College Board shows that in 2015, 21,594 secondary school participated in the AP program. Within those 21,594 schools, 2,483,452 students took 4,478,936 AP exams (*Annual AP Program Participation*, 2015). Growth of the AP program in the 1960's and 1970's is mainly attributed to the commitment and enthusiasm of The College Board, secondary schools, and universities. It is important to note that AP teachers themselves were some of the most enthusiastic supporters of the AP program (DiYanni, 2008). Growth of the AP program in the 1980's can at least be partially attributed to a trend that developed during that decade of AP courses and exams being taken by more juniors and even sophomores at the high school level. Some of the growth of the AP program in the 1990's and beyond can be attributed to the large amount of funding that began pouring in from both the state and the federal level (DiYanni, 2008).

Goals and structure of the AP program and The College Board

The College Board describes itself as:

> a dynamic, member-led, mission-driven not-for-profit organization governed by an elected Board of Trustees with guidance from three national assemblies and six regional assemblies. More than 6,000 two- and four-year colleges, universities, secondary schools and districts, higher education systems, and other nonprofit organizations compose the College Board. (*How We're Governed*, 2017)

The College Board is the organization that has been in charge of running the Advanced Placement program since its inception in the 1950's. What some people may not be aware of is the fact that the College Board has been around since 1900, and is also in charge of running many other programs and exams in addition to the AP program. The College Board also runs the SAT test, SAT subject tests, and the PSAT test (*About us*, 2017).

One main difference between the AP program and the IB program is that any secondary school can choose to offer as little as one AP class to its students. This is beneficial to secondary schools with smaller student populations who may not have enough student interest to offer six different IB courses, but may have enough student interest to offer one AP course. In the 2015-16 school year, The College Board oversaw and administered exams for 37 separate courses in the Advanced Placement Program (*Program Summary Report,* 2016). For the 2016-17 school year, The College Board added one more course bringing the current number of courses available up to 38 (*AP Courses*, 2017). This means that administrators of secondary schools can pick and choose which of the 38 courses they wish to include in the curriculum at their school. As of May 2016, the three most common AP courses, based on the number of schools offering the course, were Calculus AB, English Literature and Composition, and U.S. History. One other interesting note is that in May 2016, over 2,000,000 AP exams were taken by high school seniors, over 1,800,000 AP exams were taken by high school juniors, over 600,000 AP exams were taken by high school sophomores, over 175,000 AP exams were taken by high school freshmen, and over 6,900 AP exams were taken by students that have not yet entered high school (*Program Summary Report,* 2016).

Every AP class taken culminates with an AP exam that is typically administered during the first two weeks of May. For 2017, the AP exams will take place from May 1st – May 12th (*Exam Dates and Fees*, 2017). In 2018, the AP exams will take place from May 7th through May 18th (*2018 Exam Dates*, 2017). The College Board lists predetermined dates and times for each and every AP exam to take place. For example, in 2017, the AP Calculus AB exam will take place on Tuesday, May 9th, and must start at 8am local time for each school. The College Board

goes on to say that "Early testing or testing at times other than those published by the College Board is not permitted under any circumstances" (*Exam Dates and Fees*, 2017).

Each exam is then scored on a scale of 1 – 5, with 1 being the lowest score and 5 being the highest score. The College Board described the grades as follows: A score of 5 signifies an extremely well qualified student; a score of 4 signifies a well qualified student; a score of 3 signifies a qualified student; a score of 2 signifies a student who is possibly qualified; and the College Board does not offer any recommendation to a student who scores 1 on any exam. The College Board goes on to further explain they view the word qualified as meaning "you have proven yourself capable of doing the work of an introductory-level course in a particular subject in college" (*About AP Scores*, 2017). It is these numbers on these exams that colleges and universities look at to determine whether or not to grant credit or placement for incoming students.

Current AP mathematics classes

The College Board currently has three different mathematics classes that secondary schools can choose to offer to their students. These courses are AP Statistics, AP Calculus AB, and AP Calculus BC (*AP Courses*, 2017). The College Board describes AP Statistics as being "equivalent to a one-semester, introductory, non-calculus-based, college course in statistics" (*Statistics Course Description,* 2010, p. 4). They go on to further explain that the purpose of AP Statistics "is to introduce students to the major concepts and tools for collecting, analyzing and drawing conclusions from data" (*Statistics Course Description*, 2010, p. 4). The four conceptual themes of the AP Statistics course are:

1) Exploring Data: Describing patterns and departures from patterns
2) Sampling and Experimentation: Planning and conducting a study

3) Anticipating Patterns: Exploring random phenomena using probability and simulation
4) Statistical Inference: Estimating population parameters and testing hypothesis

(*Statistics Course Description*, 2010, p. 4).

Despite the fact that AP Statistics is designed to be equivalent to a one-semester college course, most high schools offer AP Statistics as a one-year course (*Statistics Course Description*, 2010). The College Board describes AP Statistics as being an excellent course for secondary students who have already completed a second year of Algebra, and who possess the ability to reason quantitatively. For students who take a course equivalent to Algebra 2 their junior year of high school, and who plan on studying calculus in college, The College Board warns that taking AP Statistics alone isn't the best course of action to prepare for calculus in college. Instead, they suggest that students who find themselves in this situation take both a pre-calculus course along with AP Statistics at the same time. Lastly, The College Board encourages students who have the appropriate mathematical background, to take both AP Statistics and AP Calculus while in high school (*Statistics Course Description*, 2010). As a side note for secondary school administrators and teachers who are considering offering AP Statistics as a course option, The College Board strongly recommends that students who take AP statistics have regular access to computers. They describe the computer as "an essential tool for structured inquiry", and they conclude that, "because the computer is central to what statisticians do, it is considered essential for teaching AP Statistics" (*Statistics Course Description*, 2010, p. 10).

The College Board offers two different calculus courses. They are titled AP Calculus AB and AP Calculus BC. The College Board explains the difference between AP Calculus AB and AP Calculus BC in the following way:

> AP Calculus AB is roughly equivalent to a first semester college calculus course devoted to topics in differential and integral calculus. AP Calculus BC is roughly equivalent to both first and second semester college courses; it extends the content learned in AB to different types of equations and introduces the topic of sequences and series. (*AP Calculus AB and AP Calculus BC – Course and Exam Description,* 2016. p. 4)

The College Board explains that for both of these classes, they want students to understand the how and why behind all of the mathematics involved. To help foster this deep level of understanding, The College Board explains that both AP Calculus courses are "designed to develop mathematical knowledge conceptually, guiding students to connect topics and representations throughout each course and to apply strategies and techniques to accurately solve diverse types of problems" (*AP Calculus AB and AP Calculus BC – Course and Exam Description,* 2016, p. 4). The College Board listed the big ideas for both AP Calculus courses as: Limits, Derivatives, Integrals and the Fundamental Theorem of Calculus, and for AP Calculus BC only, series. The College Board further explained six mathematical practices for both AP Calculus courses. These six mathematical practices are: reasoning with definitions and theorems; connecting concepts; implementing algebraic/computational processes; connecting multiple representations; building notational fluency; and communicating (*AP Calculus AB and AP Calculus BC – Course and Exam Description,* 2016).

As for a student receiving college credit for taking an AP mathematics courses, in a similar fashion to the IB mathematics courses, every college or university has their own set of guidelines. Many post-secondary institutions require a score of at least 3 on the AP exam in order to obtain college-level credit or placement. However, there are also a large number of colleges and universities who require a score of at least 4 or even a 5 on the AP exam in order to

receive college level credit or placement. Unfortunately, there are a small amount of post-secondary institutions that refuse to give credit to students for taking an AP mathematics course (Worthington Schools District, 2012). The situation of not knowing which colleges and universities might give credit for taking an AP mathematics course can certainly at times be confusing and/or frustrating for secondary school students and their parents. However, there is some good news in regards to this situation. In August of 2015, the state of Illinois passed a bill stating that:

> Beginning with the 2016-2017 academic year, scores of 3, 4, and 5 on the College Board Advanced Placement examinations shall be accepted for credit to satisfy degree requirements by all institutions of higher education. Each institution of higher education shall determine for each test whether credit will be granted for electives, general education requirements, or major requirements and the Advanced Placement scores required to grant credit for those purposes. (Illinois General Assembly, 2015)

Bills such as this one from Illinois certainly will help to provide clarity to secondary school students and their parents in regards to getting college credit for earning a score of at least 3 on an AP exam. Also, according to Jeff Peterson of The College Board, as of August 2015, 17 states have similar policies granting "college credit state-wide or system-wide to students earning scores of 3 and higher on AP Exams" (Peterson, 2015).

What does research on AP mathematics classes say?

One study was done involving over 36,000 students who graduated from high schools that were in the Chicago Public School (CPS) district between 2005 and 2007. This study used 10^{th} grade GPAs, PLAN test scores, and demographic information to estimate the probability of a student taking an AP mathematics or AP science course. The researchers then applied the same

estimated model to "simulate the propensity for taking AP mathematics or science courses for students who attend schools that do not offer these courses, essentially simulating what would have happened if these students had gone to schools that offered AP math and science courses" (Kelly-Kemple, Proger, & Roderick, 2011). They then looked at these similar groups of students, and determined that students who enrolled in an AP mathematics course were about 8% more likely to attend a four-year college or university compared to students with similar abilities who didn't have an option of taking an AP mathematics course at their school. They also found that the group of students who had taken an AP mathematics course was about 6% more likely to persist in college for the first two years compared to the other group who didn't have the option of taking an AP mathematics course. The researchers concluded that taking an AP mathematics course did have a significant positive effect on the college outcomes of the students. However, the researchers cautioned that it is possible that the results had a positive bias towards AP classes because it is next to impossible to measure student motivation levels (Kelly-Kemple, Proger, & Roderick, 2011).

Another researcher (Hoepher, 2010) did a study involving 881 students who were currently pursuing a major in science, technology, engineering, or mathematics (STEM) at the University of California. The students in this study had all taken at least one AP course while they were in high school. The researcher wanted to find out from these students how beneficial, they felt, those AP courses were that they took in high school. In regards to AP Calculus specifically, the researcher stated that:

> Students verbally praised AP Calculus as a practical course, one that if taken, reaped benefits across disciplines. According to students, AP Calculus proved not only helpful

> for college math courses, but also relevant for entry-level engineering, computer science, and chemistry courses. (p. 108)

Not every study on AP mathematics reached a positive conclusion. One researcher used data from The National Educational Longitudinal Study who first surveyed a large sample of 8th graders throughout the United States in the spring of 1988. The study then followed up with the group of students for another survey in 1990, 1992, 1994, and 2000. Using the results of this survey, the researcher came to the conclusion that if a student simply participates in an AP mathematics course, that alone cannot be used to predict post-secondary mathematics achievement (Kremers, 2010).

In addition to these studies on AP mathematics classes, there are several studies about the AP program as a whole that are worth noting. In 2014 The College Board put out a publication titled *AP Student Success at the College Level – Recent Research*. In this publication, The College Board listed benefits for AP students who achieve a score of 3 or higher on an AP exam. Among the benefits The College Board listed were: "AP students perform well in subsequent college courses in the discipline"; and "AP students are more likely to graduate (from college) within four years" (*AP Student Success at the College Level – Recent Research*, 2014, p. 3).

From 2002 – 2006 the National Center for Educational Achievement (NCEA) conducted research that looked at the relationship between students' participation in AP courses and their subsequent success in college. The major findings of their research included: Simply taking an AP course is not related to college success; taking an AP course and passing the subsequent AP exam is related to college graduation rates; Academic preparation in earlier grades is critical for students' readiness for AP classes. In regards to the last statement, the study goes on to say that students need strong academic preparation in grades K-8 to simply have a reasonable chance of

successfully completing an AP course and then passing the subsequent AP exam. The study concluded by saying, “educators and policymakers who are serious about expanding access to AP courses and exams should focus their attention on ensuring that elementary, middle, and high school curricula prepare all students for college-level work” (National Center for Educational Achievement, 2010).

Conclusions about AP mathematics classes

Although every piece of research on AP mathematics classes isn’t glowingly positive, there has been enough research done to suggest that taking an AP mathematics course and then passing the subsequent AP exam can have a significant long-term positive effect. Taking an AP mathematics course and passing the subsequent AP exam has been shown to: lead to a higher likelihood of attending a four year college or university, lead to a higher likelihood of persisting in college for at least two years, and lead to a higher GPA in mathematics courses while in college (Kelly-Kemple, Proger, & Roderick, 2011 & *AP Student Success at the College Level – Recent Research*, 2014). If any student is faced with the decision of taking an AP mathematics course their senior year of high school, or taking a non-college credit granting mathematics course, enough research exists to suggest that taking the AP mathematics course would be advised.

Dual Credit Programs

Dual Credit Defined

Any discussion about dual credit classes should first begin by defining the terms dual credit and dual enrollment. This is important because a look through other research on this topic yielded slightly different definitions of these terms. For example, a study was done in 2014 that explored the impact dual credit classes had on post-secondary outcomes. In this study, right after the authors give their definition of dual credit, they then explained that dual credit is "also known as dual-enrollment or concurrent enrollment" (Giani, Alexander, & Reyes, 2014, p. 200). Moreover, this was not the only study that combined the terms. In 2011, a study was done that stated, "The term dual credit enrollment is used interchangeably with concurrent enrollment" (Schmit, 2011, p. 5). These authors are not incorrect in their statements; however it is easy to see how someone reading their studies can come away mistakenly believing that dual credit and dual enrollment mean the exact same thing, when that isn't always the case.

> The Illinois Board of Higher Education (IBHE) defined dual enrollment as:
>
> any situation in which an individual is concurrently enrolled at both a secondary (high school) and post-secondary (college or university) institution. However, the term is frequently used to distinguish from dual credit courses and used to identify situations in which a high school student enrolls in a college course for college credit only. (Illinois Board of Higher Education, n.d., p. 1)

This is the definition of dual enrollment that will be used for this research paper. The IBHE went on to define dual credit as "a college course taken by a high school student for which the student is awarded both college and high school credit" (IBHE, n.d., p. 1). This is the definition of dual credit that will be used for this research paper.

Another important note about dual credit courses is that they can take place at the high school, or they can take place at the post-secondary institution. Some dual credit courses are taught at the high school, during regular school hours, by qualified high school faculty members and are recognized by the college as meeting college requirements. Other times, dual credit courses can be taught at the "college campus by regular college faculty and are recognized by the high school district as meeting high school requirements" (IBHE, n.d., p. 1). The main focus of this research paper is to analyze potential college-credit granting mathematics classes that high school students may be able to take at their high school. Going forward, this research paper will mainly examine dual credit courses that take place at the high school campus.

One last piece of information that needs to be mentioned here is that the definitions of dual credit and dual enrollment can sometimes differ from state to state! Some states have specifically defined definitions of dual credit and dual enrollment, while others do not. Further confusing matters is the fact that not all of the states' definitions of dual credit and dual enrollment are exactly the same (Education Commission of the States, 2016). If one intends to research dual credit or dual enrollment courses in a specific state, first understanding that state's definition of these topics is imperative.

History of Dual Credit programs

Unlike the AP and IB programs, all dual credit programs are not run by one organization. This makes it a bit more challenging to pinpoint the exact beginnings of dual credit programs. Some studies say "dual credit programs and policies have operated in some states and localities since the 1950s" (Taylor, 2015). Although it is most likely that studies claiming dual credit programs started in the 1950s are referring solely to the AP and IB programs (Kim, 2008). A study done by the Office of Community College Research and Leadership in Illinois states:

> Dual credit programs were first established in the 1970s, gradually gaining popularity in the 1980s, and expanding enormously through the 1990s. These programs are designed to allow high school students to begin college-level coursework and simultaneously earn high school and college credit. (Barnett, E., Gardner, D., & Bragg, D., 2004)

Much like AP and IB courses, dual credit courses have been gaining in popularity this century as well. The National Alliance of Concurrent Enrollment Partnerships says that dual enrollment classes had an annual growth rate of over 7% per year from the 2002-03 school year to the 2010-11 school year. They also say that in 2011 over 1,400,000 high school students enrolled in a dual enrollment course (*Fast Facts about Dual and Concurrent Enrollment*, n.d.).

One significant difference between dual credit courses and AP or IB courses is that dual credit courses are actual credit-bearing college courses. This means that students will earn a college grade based on many assessments throughout the length of the course (*What is Concurrent Enrollment?*, n.d.). This is in stark contrast to AP and IB courses where a student has to take one high stakes exam at the completion of the course which usually determines if the student receives any college credit (as discussed in chapters 2 and 3).

Goals and structure of Dual Credit programs

"Currently, within states and on a national level, no common standards exist for concurrent enrollment courses. There is no definition of what constitutes a college-level course or what is considered college-level work" (Buzynski, 2011, p. 49). Despite this fact, there are many reasons why high school students should be looking into taking dual credit classes if available. Schmit (2011) stated "conducting college level work while still in high school can better prepare a student for the demands of post-secondary education" (p. 36). In addition, other

research indicated that participation in dual credit programs leads to significantly higher educational aspirations by students (Smith, 2007).

There are also many reasons why high schools and post-secondary institutions would want to create partnerships to offer dual credit classes. “Through collaboration, high schools can learn more specifically what is expected from students at the college level and alter their current academic and curricular practices as needed to prepare students effectively” (Schmit, 2011, p. 39). High schools also gain prestige from being able to say that they offer actual college courses. Post-secondary institutions also benefit from dual credit classes through increased revenue and access to more potential enrollees. Top high school students who otherwise may not have considered a community college or local university may now be attracted to attend if they already have completed some course work from that institution prior to graduating high school. In this manner, dual credit programs can create a recruitment strategy for community colleges and local universities (Giani, Alexander, & Reyes, 2014).

Dual credit courses require a partnership between a high school and a local community college or local university. To formalize their partnership, the high school or school district signs a memorandum of understanding (MOU) that outline each partners responsibilities. The MOU’s are legally binding documents that: allow the partners to agree upon intended goals; specify how the financial responsibilities will be shared; specify what courses will be offered; specify if and how the high school and college faculty will collaborate (Cassidy, Keating, & Young, 2011).

Current Dual Credit mathematics courses

Every MOU between a high school and a post-secondary institution can include different types of mathematics courses as well as a different number of different mathematics courses to offer to the high school students. For example, the City Colleges of Chicago have an agreement

with the Chicago Public Schools in which each high school in CPS can offer any amount of five potential mathematics courses to their students (*Dual Credit with CPS High Schools*, 2017). These five mathematics courses are: MATH 118 – General Education Math; MATH 121 – Math for Elementary Teachers; MATH 125 - Introductory Statistics; MATH 140 – College Algebra; MATH 143 – Pre Calculus (*Courses*, 2017). Across the country there are a multitude of different mathematics course offerings that high school students can take for dual credit. An attempt at identifying each and every one is beyond the scope of this research. Instead, to get a good understanding of the different types of dual credit mathematics course offerings that are available throughout the United States, three more separate post-secondary institutions from different states are analyzed.

Portland Community College (PCC) in Oregon stated that in the 2015-16 school year, 62 area high schools and over 7,500 students participated in dual credit programs with PCC. Some of those 62 high schools offered no dual credit mathematics courses, some offered one dual credit mathematics course, and many offered multiple dual credit mathematics courses. Through all 62 of the high schools, there were eight different dual credit mathematics courses that were offered in cooperation with PCC. Those courses are: MTH 95 – Intermediate Algebra; MTH 111 – College Algebra; MTH 112 – Elementary Functions; MTH 243 – Statistics I; MTH 244 – Statistics II; MTH 251 – Calculus I; MTH 252 – Calculus II; MTH 253 – Calculus III (Portland Community College, 2016).

The University of Missouri – Kansas City (UMKC) offers five different dual credit mathematics courses in cooperation with local high schools. The dual credit mathematics courses offered in cooperation with UMKC are: MATH 120 – Pre Calculus, MATH 125 – Trigonometry; MATH 202 – Analytic Geometry; MATH 210 Calculus I; MATH 220 – Calculus II (University

of Missouri – Kansas City, 2017). While Purdue University Northwest also offers five different dual credit mathematics courses in cooperation with local high schools. Those courses are: MA 153 – College Algebra; MA 154 – Algebra and Trigonometry II, MA 161 – Plane Analytic Geometry and Calculus I; MA 162 – Plane Analytic Geometry and Calculus II; MA 213 – Finite Math (Purdue University Northwest, 2017). As can be seen, high school administrators usually have many different options to choose from when they have to make a decision on which dual credit mathematics courses to offer to their students.

What does research on Dual Credit mathematics courses say?

A study done by Speroni (2011) looked at all public high school students in Florida who graduated from high school in 2001 and 2002, and tracked their outcomes in post-secondary institutions through the summer of 2007. This study analyzed whether taking certain dual credit courses had any impact on high school graduation, college enrollment, and the likelihood of students obtaining an associates or bachelor's degree. One of the dual credit courses this study analyzed was College Algebra, and some fairly interesting conclusions were drawn. First, this study concluded that "taking College Algebra in high school increased associate degree attainment by 23 percentage points", and "bachelor's degree attainment by 24 percentage points" (Speroni, 2011, p. 47). Second and perhaps even more eye opening was the conclusion that "College Algebra is a gatekeeper course, and having it completed at the onset of college seems to have helped students make progress toward a degree" (Speroni, 2011, p. 47).

Giani, Alexander, & Reyes (2014) did a similar study in the state of Texas. This particular study looked at students who were high school freshmen in the 2000-2001 school year and subsequently graduated high school in 2004. The study then went on to analyze those students' post-secondary outcomes. This study first stated that vocational or occupational dual

credit courses had little impact on students' post-secondary outcomes. However, the researchers found that dual credit courses in core subjects like mathematics were found to "significantly increase the likelihood that students would enroll in a college or university, persist to their second year, and complete a degree or certificate. Dual credit math courses were particularly influential in promoting baccalaureate attainment" (Giani, Alexander, & Reyes, 2014). No research speaks critically about dual credit mathematics courses specifically.

In addition to these few studies which specifically mentioned dual credit mathematics courses, there have been a few studies on dual credit classes as a whole that are worth mentioning. First, Swanson (2008) did a study with a nationally representative student population in which she found that students who participated in a dual credit course were "12% more likely to enter college within 7 months of high school graduation", and "11% more likely to persist through the second year of college than non-participating students" (p. 3). Students who participated in dual credit courses and then had a higher rate of persistence to the second year of college is a common theme among research that had been done. Another study done in Texas found that "dual credit participants were more likely to persist in college to a second year in both two year and four year public institutions in Texas" (Appleby et al., 2011, p. 82). In addition, there was a five year study done by Buzynski (2011) in Iowa that concluded "students who earned college credit in high school were 9% more likely to persist to the second year of college than students who had not" (p. xiv). She also concluded that "consistently, for each of the five years, the first semester college mean GPA was always higher among students who had earned college credit in high school than that of students who had not" (p. xiv).

While most of the research on dual credit mathematics classes, and dual credit classes in general, is positive that doesn't mean that dual credit courses are free from critical remarks. The

American Association of State Colleges and Universities, Washington, DC (2002) put out a study in which they listed a few concerns they had about dual credit courses. One of the concerns they had was the quality of the program taught at the high school. They mentioned that some college professors feel that dual credit courses are not rigorous enough. Another concern they noted is that sometimes high school teachers may not be adequately prepared to teach a college-level course. One other concern they noted was with the transferability of credits for students. They mention that although most colleges and universities will work with students to transfer in and accept credits earned through dual credit courses, those credits may not fully transfer, depending on the policies of each post-secondary institution. Whether or not credits earned through a dual credit course will transfer to another specific post-secondary institution, is something that students and their parents should look into before deciding to enroll in a dual credit course. Luckily, there are websites like: https://www.transferology.com which can aid students in helping them find out if their credits obtained through dual credit courses will easily transfer to other post-secondary institutions in which they wish to attend.

Conclusions about Dual Credit mathematics courses

If a student hasn't completed the equivalent of four years of secondary mathematics designed for college bound students by the end of their junior year of high school, then they may not be eligible to take an AP calculus course (*AP Calculus AB and AP Calculus BC – Course and Exam Description,* 2016). If a student isn't eligible to enroll in an AP calculus course, but does have the option of enrolling in a dual credit mathematics course like college algebra, most research indicated that taking a dual credit mathematics course would be advantageous for the student when compared to not enrolling in an AP, IB, or dual credit course. However, before enrolling in any dual credit course, students and their families would be advised to first

investigate whether or not the credit earned in the dual credit course will transfer to the post-secondary institution in which the student is planning to attend.

Summary and Conclusions

As noted in the introduction, many incoming college freshmen are inadequately prepared to take college level mathematics courses. In fact a 2009 study by Bailey, Jeong, & Cho (2009) looked at over 250,000 students who enrolled at 57 various community colleges throughout the United States. They found that 59% of these students were referred to a developmental mathematics course! Out of those students who were referred to a developmental mathematics course, only 20% of them completed their developmental mathematics sequence and their first college-level mathematics course within three years of enrollment (Bailey, Jeong, & Cho, 2009). The same study went on to further explain that "most high school students who enroll in remediation believe that they are prepared for college" (p. 268). Clearly there is some disconnect between student's perceptions of how ready they are for college-level mathematics course work, and the reality of the situation. One way a student can avoid needing to take non-credit bearing remedial mathematics class after high school is to earn credit from taking a college-level mathematics class while in high school.

This study took an in depth look at three programs currently available in high schools across the United States that give students a chance to earn a college-level mathematics credit before graduating from high school. The names of these programs are: International Baccalaureate, Advanced Placement, and Dual Credit. The overwhelming majority of research suggested that students who enroll in these classes: are more likely to enroll in a college or university; are more likely to persist in college, are more likely to attain a bachelor's degree in a reasonable amount of time, and are more likely to have a higher GPA in college.

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