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STANDARDIZED TESTS: EFFECTS ON SCIENCE EDUCATION AND DIVERSITY IN SCIENCE

by

R. A. Rucker

A Thesis Submitted in Partial Fulfillment
Of the Requirements for the
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The members of the Honors Thesis Committee appointed
to examine the thesis of Rachel Rucker
find it satisfactory and recommend that it be accepted.

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ABSTRACT

Standardized Tests: Effects on Science Education and Diversity in Science

R. A. Rucker

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Standardized tests are ubiquitous in the American educational system. The excessive use of standardized tests has led to a decrease in taught content and has pushed teachers at the high school level to adopt less effective teaching styles that are also extremely common for introductory STEM courses at the undergraduate level. The heavy reliance on ACT and SAT scores for acceptance into college is misplaced, as the ACT/SAT are poor predictors of STEM college graduation. Also, underrepresented students (women, racial minorities, and lower socioeconomic groups) are disproportionately impacted by the heavy use of standardized tests. These students tend to score lower on the ACT/SAT, which makes it more difficult for them to get into higher education and may also make them feel unqualified to obtain a STEM degree. Therefore, adopting a more engaging style of teaching and dropping test requirements, both of which can increase diversity in STEM, could ameliorate the issues that arise from standardized tests and better prepare students for their next steps in STEM. An effective science education, one that focuses on student engagement, is more important than standardized test scores in providing all students with an equal opportunity to succeed.

KEYWORDS: Standardized Tests, Education, Diversity, STEM

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CHAPTER ONE

Introduction

The ubiquitous standardized test culture is so pervasive that even in fictional worlds like Harry Potter, there are two well-known standardized tests that students take (one of which is quite aptly named the Nastily Exhausting Wizarding Test, often abbreviated as N.E.W.T.). In the wizarding world, students must first meet a cutoff "grade" on their O.W.L.s (Ordinary Wizarding Level) test in order to take the next upper-level course within that subject area. Depending on what career a student wants to have, it is imperative for them to meet this cutoff in certain subjects, because there are professions that require students to have obtained certain distinctions on the N.E.W.T.s exams, which are taken after O.W.L.s, to be considered for a job. For example, Harry Potter would not have been able to become an Auror if Professor Snape had continued to teach potions. This is because Harry only earned an 'Exceeds Expectation' on his potions O.W.L. and Professor Snape required students to obtain the next highest distinction in order to take his N.E.W.T.s level potions class (Rowling, 2003, p. 175). Of course, with Professor Slughorn as the potions professor the next year, he allowed students with an 'Exceeds Expectation' into his N.E.W.T.s level potions class (Rowling, 2003, p. 175), and Harry ultimately was able to become an Auror (https://www.hp-lexicon.org/event/harry-potter-becomes-head-of-the-auror-department/#:~:text=After%20joining%20the%20Aurors%20at,of%20the%20Department%20in%202007.).

Often, students' tensions and stress levels rose in nervous anticipation of the fateful day that their O.W.L.s started because their futures literally depended on how well they did. For example, on the night before the O.W.L.s began, Rowling describes the atmosphere at dinner as "a subdued affair" (Rowling, 2003, p. 710) and "an uncomfortable sort of an evening" due to everyone "trying to do some last-minute studying" (Rowling, 2003, p. 711). She even describes how the students had trouble falling asleep the night before the exams (Rowling, 2003, p. 711). This gloomy and stressful mood is due to the nervous actions of students, who are working as hard as possible to be prepared. Some are working so hard, that even the morning of the exams, students are practicing incantations under their breath and rereading parts of their textbooks during breakfast (Rowling, 2003, p. 711).

The O.W.L. exams take up precious class time that could be spent teaching students more content. In the wizarding world, the exams are "spread over two successive weeks" and had both a theory and a practical application portion (Rowling, 2003, p. 708). This is on top of the time that the professors set aside to review material. Before the O.W.L.s started, the "teachers were no longer setting them homework; lessons were devoted to reviewing those topics their teachers thought most likely to come up in the exams" (Rowling, 2003, p. 706). How prepared students felt for these exams also depended on the preparation their professors provided them.

In the wizarding world, it is especially important that students are able to execute the various spells successfully or correctly brew a potion. However, ineffective teaching, even within the bounds of the wizarding government's educational requirements, could not prepare students for the real world, and in some cases even the O.W.L. exam. For example, Professor Umbridge taught the Defense Against the Dark Arts class during Harry's fifth year, but her teaching method was based on "following a carefully structured, theory-centered, Ministry-approved course of defensive magic" (Rowling, 2003, p. 239). Professor Umbridge's philosophy was that "As long as you have studied the theory hard enough, there is no reason why you should not be able to perform the spells" (Rowling, 2003, p. 244).

This is a major contrast from Professor Lupin, who had students practicing the Riddikulus charm during their first boggart lesson. Professor Lupin's boggart lesson was so successful among students that Ron describes the class as "the best Defense Against the Dark Arts lesson we've ever had" and even Hermione approvingly refers to Professor Lupin as "a very good teacher" (Rowling, 1999, 140). Understanding the concepts are important but being able to reinforce those concepts through practical use of the material can be extremely beneficial in learning new material.

What Harry and his friends experienced within the educational system at Hogwarts is quite similar to what Muggle students experience. Muggles also face the challenge of high stakes standardized testing, where a certain score can largely impact a student's future. Teachers are forced to take class time to prepare for the tests and the time to take the tests, too. While teachers focus on providing their students with the concepts needed to do well on the standardized tests, they may also neglect the importance of engaging their students, a teaching style exemplified by Professor Lupin and praised by Harry and his classmates.

Our overreliance on standardized tests has led to an ineffective science education environment, where high school teachers are pressured to use poor teaching methods that focus on memorizing standardized test material over building analytical thinking skills. This is due to the particularly large importance that standardized tests play in obtaining college credit for classes taken in high school, admission into college, and admission into post-baccalaureate education (such as the AP tests, ACT and SAT, and GRE, respectively). The impact of these tests is especially prominent in STEM (science, technology, engineering, and mathematics) fields, where certain scores are supposedly required for future success. For the ACT, the ACT Inc. has set the STEM benchmark score to be 26, which is an average of a student's math and science subset scores (Sundquist, 2017). By meeting or exceeding the Benchmark score, ACT says "you have at least a 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in specific first-year college courses" that correspond to science and math (Sundquist, 2017). Therefore, if students do not meet the Benchmark STEM score, they may not pursue a STEM major, even if they are interested in STEM, because they may believe that they will not be able to do well in the major. Also, for students who have the same SAT or ACT math score, "the higher their verbal score, the less likely they [are] to pursue or complete a postsecondary STEM degree" (Borman, et al., 2016, p. 5). While the study did not directly address why this is, it is possible that students feel, especially if their verbal score is higher than their STEM score, that they are better at reading and writing. Therefore, based on the scores they receive, they choose a language-based discipline rather than STEM. The implications of these test scores are wide-ranging and include the increased pressure on high school teachers and students.

These tests also have more direct impacts on underrepresented students in the STEM discipline, specifically women, ethnic minorities, and those from low socioeconomic brackets, as these underrepresented students often score lower on the ACT and SAT. With universities and colleges still including these scores as part of their admissions process, it may place these students at a disadvantage for getting into higher education. However, students who score lower on the ACT/SAT are still able to do just as well in college as their peers. Also, students who have low science and math sub scores on these tests may self-select out of STEM, even if they are interested in pursuing STEM, because they do not believe they are good enough. Therefore, these standardized test requirements may be hindering the diversification of higher education, especially since test-optional universities/colleges have seen an increase in applications from diverse students.

I argue that an effective science education, one that focuses on student engagement, is more important than standardized test scores in providing all students with an equal opportunity to succeed. To do so, I will further discuss the impact standardized tests have on the teaching structure within high school and the limited ability of these tests to predict success; discuss the transition from high school to college teaching; explore new efforts to prepare students for undergraduate STEM education, and explain how a change in teaching style could positively impact STEM education while ameliorating issues that arise due to the use of tests, such as gender, racial, and economic disparities. Teaching reform could better prepare students for their next steps in their educational careers.

CHAPTER TWO

Impact of Standardized Tests on High School Teaching

Standardized tests have become an inescapable facet of the United States public education system. The rounds of yearly tests for public school children were spurred by the No Child Left Behind (NCLB) federal legislation enacted in 2001 (Au, 2007). As part of NCLB, schools were required to set Adequate Yearly Progress (AYP) goals for mathematics, language arts, and science (Aydeniz & Southerland, 2012). While on the surface, the goal of having all students attain at least a certain level of competency in mathematics, language arts, and science regardless of school is a good one. However, the way the law was enacted led to negative side effects. Specifically, if a school failed to meet their AYP goals, they were “threatened with sanctions (e.g., lessening of funds), including the take over of the school by the states” (Aydeniz & Southerland, 2012, p. 234). For teachers, if they were deemed to be part of the reason the school was failing to meet their AYP goals, they could legally be fired (Crisafulli, 2006, p. 614). Also, teachers’ bonuses may be linked to how well their students’ test scores improved from the previous year, which caused teachers to avoid teaching students that they believed would not make large gains on their exams (Morgan, 2016). This leads to a grave situation where one test score largely impacts the future of the teacher as well as the school district, thereby raising the stakes for the students to do well. Due to the outsized role tests play in public education, it is imperative that we understand how they impact teaching style, form of student assessments, and teachers’ views of the efficacy of these tests.

One of the major effects of standardized tests can be seen by the significant restructuring of curricula to focus only on tested subjects. A review of 49 individual studies, which included K-12 education and all subjects (history, English, STEM, etc.), found that "nontested subjects were increasingly excluded from curricular content" especially in secondary education (Au, 2007). This is not surprising given the high stakes of the tests; teachers want to do everything in their power to cover as much potential test material as well as they can. While this study addressed broad educational changes, this trend is also seen in research that specifically addresses science education.

In a study that focused on 161 secondary school science teachers, where 85 (53%) taught at a high school, 86% of the secondary school teachers "felt encouraged by their school administration to organize their lessons based on the objectives of standardized tests administered in their relative states" (Aydeniz & Southerland, 2012, p. 246-247). While this does not directly state that secondary science teachers narrow their scientific content, teachers' responses to open-ended questions linked the pressure to reorganize their lessons led to a decrease in the amount of content taught. In the open-ended questions in the study, teachers explained that "the pressure of improving students' test scores encouraged them to reduce the content of their enacted curriculum to students' acquisition of factual knowledge" and that the standardized tests did not support "students' acquisition of inquiry skills" (Aydeniz & Southerland, 2012, p. 245). In science, the ability of students to ask and answer questions through self-directed curiosity about how the world works is an essential component of higher level scientific exploration, such as research.

However, if students are only ever presented scientific facts and are taught that memorizing facts is the name of the game, they do not experience the heart of science. These effects on curricula and more fact-based teaching led 60.5% of secondary science teachers to believe that standardized testing cannot improve students' scientific learning, with even 37% stating that the changes they make contradict "what they believed teaching and learning of science should look like" (Aydeniz & Southerland, 2012, p. 245-247). This striking statistic is also in agreement with more general studies on the effects of standardized tests.

Again, the Au study, which included K-12 education and all subjects (such as history, English, STEM, etc.), found that there was an "increase in teacher-centered instruction associated with lecturing and the direct transmission of test-related facts" (Au, 2007). This agrees with the comments that the secondary teachers made in the Aydeniz and Southerland study and directly contradicts new research that supports active student engagement as a better form of instruction than the teacher lecture format. (This research will be further discussed in chapter 5.) The Au study also found an increase in "teaching of content in small, individuated, and isolated test-size pieces, as well as teaching in direct relation to the [standardized] tests rather than in relation to other subject matter knowledge" (Au, 2007). This can have an especially detrimental impact on science education because basic scientific concepts such as chemical interactions impact biology, chemistry, and physics in the same way and require students to be able to connect these concepts. Science should not be taught in isolation, but instead as the interconnected subject it is.

Not only is the curricula narrowed to focus on test material, but a significant amount of class time is spent on test-taking and on students learning and practicing test-taking strategies. Currently, some school districts have as many as thirty-three standardized tests per year and spend up to 25% of the school year preparing for and conducting standardized tests (Kamenetz, 2015). It has now become common for students to receive standardized test preparation or take a mental break after the standardized tests due to test exhaustion during class time that would previously have been used for learning class material. In the study of 161 secondary science teachers, Aydeniz and Southerland found that 90% of the teachers spent class time on test-taking strategies (Aydeniz & Southerland, 2012, pp. 240, 244). This allocation of class time to test-taking strategies becomes even more common in classes that are more geared towards standardized tests, such as Advanced Placement (AP) courses. In a study where teachers were asked to compare how they taught their high school AP science course to either a regular or honors science course, the researchers found that there was significantly more emphasis on test-taking strategies in the AP science course than either the regular or honors science course (Judson, 2017, p. 242). However, other teaching goals, such as memorizing science vocabulary and/or facts, having students work in small groups, or doing hands-on lab activities, were not statistically different for AP science courses compared to regular or honors science courses (Judson, 2017, p. 236-237).

Teachers feel the need to prepare their students as best as they can for these standardized tests. Therefore, some teachers mimic the standardized test style in their own in-class tests. 93% of the secondary science teachers “stated that they made significant changes in their assessments due to the standardized testing” (Aydeniz &

Southerland, 2012, p. 247). This change in how teachers assessed their students was driven by a belief that it was not "fair to their students to take the [standardized] test without adequate preparation" for 75% of the teachers (Aydeniz & Southerland, 2012, p. 247-248). Clearly teachers want their students to do well on the standardized tests, even if it causes them to spend precious class time in ways that they don't believe will help their students gain skills necessary for a future scientific career. The Aydeniz and Southerland study also noted that often the changes that the secondary teachers made in their assessments led to measuring "students' acquisition of scientific facts rather than their acquisition of scientific inquiry and critical thinking skills, and students' development of conceptual understanding" (Aydeniz & Southerland, 2012, p. 250). Again, this is seen as a negative impact on science education.

While teachers in all subjects feel the necessity to isolate and narrow their content, in science education they also feel disheartened about how the standardized tests cover scientific material. Seventy-two of the 85 high school teachers surveyed in the study indicated that "the standardized tests only measured their students' understanding of basic science concepts that are covered in middle school and not the science content that they taught in their courses" (Aydeniz & Southerland, 2012, p. 246). Also, 88% of all the secondary science teachers believe that their state's standardized test does "not measure the content that they taught in their courses" (Aydeniz & Southerland, 2012, p. 246). This is not exactly surprising as even at the high school level science becomes specialized into biology, chemistry, and physics, with even more specializations within each major topic, such as environmental biology versus anatomy. Given that standardized tests are only allotted a few questions per subject area and a strict time limit, the tests are not able to directly test high level knowledge in each specific area but instead must be more generalized.

Also, depending on the high school, students are often able to select which science classes they want to take beyond the usual general biology and general chemistry requirement. In this case, a single test focused in general on science can function as a poor measurement for students' understanding of science in each of these more specific areas. Of course, the state standardized tests could be made to probe the upper levels of science more directly. However, it would be difficult to make such a test fair and capable of measuring scientific understanding, since high school students are able to choose different science courses to meet graduation requirements and certain schools may not have specific classes, such as anatomy. This would require each science course to have its own specific test, but that would only exacerbate the current problem of having too many tests.

Sadly, these standardized tests may also cause schools to put science education on the back burner depending on how the state deals with standardized test scores, as allowed by the federal government. States are "given the flexibility whether to include students' science achievement scores in their calculation of their AYP objectives or not" (Aydeniz & Southerland, 2012, p. 237). While this may decrease some of the pressure on science teachers to have their students obtain high test scores, it likely still has some of the previously discussed negative outcomes, such as narrowing the curriculum, in order to prepare students for the standardized tests. Also, the science teachers may be pressured into focusing on aspects of their class that could impact school funding, such as requiring more written explanations to benefit language arts or focusing more on calculations to benefit mathematics (Aydeniz & Southerland, 2012, p. 238). Either way, the focus on a solid science education may be overlooked. With a decreased focus on science education and a decrease in inquisitive learning at the high school level due to the standardized tests, this could cause students to be underprepared for their transition into undergraduate science classes and the scientific discipline in general. While the NCLB policy has ended and has been replaced with new legislation - Every Student Succeeds Act in 2015 (U.S. Department of Education), there continues to be an increased presence of standardized tests in education.

Overall, "testing-based educational improvement policies" are deemed as "undermin[ing] the reform efforts in science education by allocating instructional time and resources in ways that do not help students to acquire the type of knowledge and skills deemed important by the science education community or the science education reform documents" (Aydeniz & Southerland, 2012, p. 248). However, there are a few secondary science teachers who do believe that standardized tests have some positive impacts that are important to mention. The general positive theme is that standardized tests "encouraged teachers to cover the state standards in their teaching in an effective manner and thus ensured the uniformity of the content taught across classrooms in their states" (Aydeniz & Southerland, 2012, p. 251). It is important to have a minimum standard or expectation for what should be taught in science classes in order to provide an equal education to all students. But requiring students to take standardized tests and using their scores to determine which teachers keep their jobs and get bonuses, has major negative effects on students, teachers, and scientific education. With the excessive testing and high stakes associated with the testing, teachers are forced to teach to the test in a way that decreases content and time that students are able to engage with the material in a thoughtful way driven by curiosity and experimentation with the concepts. Instead, we must have a balance between excessive standardized testing and effective, but equal, science education, where teachers engage with their students while still covering the basic educational objectives for their class. As Donald Campbell said, “when test scores become the goal of the teaching process, they both lose their value as indicators of educational status and distort the educational process in undesirable ways” (Kamenetz, 2015, p. 5).

CHAPTER THREE

Ability of a Standardized Test to Predict ‘Success’

To measure a students’ preparedness for college, ACT and SAT exams are common. Like the standardized tests given in elementary, middle, and high school, the ACT and SAT are comprised of multiple-choice questions, which some argue are the most effective style of questions to “test higher order cognitive skills” (Conn & Elliott, 2005). To an extent, these tests are more common in certain geographical locations. Historically, the ACT tends to dominate the Midwest and the SAT dominates the coasts. However, over the years, the number of students interested in taking both exams has risen.

A study on the percentage of Texas high school students taking the ACT and/or SAT found that those who chose to take both exams rose from 26% in 1991 to 30% in

1999 (Thomas, 2004). As schools are becoming more selective, it is believed by experts that the increase in taking both the SAT and ACT is due to students' "hopes of increasing their likelihood of obtaining admission to more selective colleges and universities" by scoring higher on one of the exams (Thomas, 2004). Students have also turned to taking the exams multiple times and/or paying for tutoring or test preparation classes as a way to increase their test scores. However, not all students are able to afford tutoring or test preparation class and even affording to take the exam itself can be a burden on their finances. This can lead to an even greater disparity between socioeconomic brackets. Ultimately, students are driven to spend lots of time, effort, and money on these tests. Therefore, it is imperative that we fully understand how effective these tests are at measuring students' success in college like they are advertised as being able to do.

First, we must discuss how success is measured in a variety of these studies. It was mentioned in a study that "The overwhelming majority of these studies [ones predicting the efficacy of standardized tests] use … freshman GPA as the criterion representing success in college" (Geiser & Studley, 2002, p. 4). Predicting first-year GPAs was actually what the ACT was originally developed for.

> The College Board … has focused on predicting first-year college grades (FYGPA) since its earliest days—in part, presumably, because Conant was interested from the first in finding tests that would identify high school students from the Midwest who not only would graduate (that was assumed) but would "perform brilliantly" at Harvard. (Bowen, et al., 2009, p. 127)

However, even if students perform, according to their GPA, very well their first year in college, if they do not complete their degree, they will not see a job benefit from going to college. Therefore, research among certain groups has shifted more towards the efficacy of standardized test scores to predict college completion within 4-6 years. One study did find that while the SAT/ACT scores "have a greater incremental power to predict college grades than to predict graduation rates … high school GPA is an even more powerful incremental predictor than is the SAT/ACT" (Bowen, et al., 2009, p. 128).

Second, it is also important to note who is doing the research. A trend that I noticed while sifting through research looking at the ability of the ACT and SAT to predict college success (however broadly defined) was that there were quite a few studies conducted by either the companies that supply the tests or people who were on the boards of other standardized test companies. This trend was also mentioned in another study saying that "Much of the research affirming the value of the SAT and ACT has been conducted by the testing organization" (Syverson, et al., 2018, p. 5). Of course, this is a major conflict of interest, and research conducted by these organizations should be more heavily scrutinized, since they earn a profit on being able to sell these test scores as effective predictors of college success.

However, while the ACT and SAT were not originally developed to predict graduation rates of students (Bowen, et al., 2009, p. 113), the research that I will discuss will focus on the tests' ability to predict graduation rates. I chose this because being able to predict if students will complete a degree is more beneficial than predicting college grades, since a degree will have a larger impact on the students' future.

There are a multitude of studies that support the argument that high school GPAs (HSGPAs) are significantly better at predicting college degree completion rates than the SAT or ACT. One of the most notable studies was conducted on about 150,000 "first-time, full-time members of the 1999 entering cohorts at flagship public universities spread across the country [United States] and in four state systems" (Bowen, et al., 2009,

p. 112). They found that high school grades were a "far better predictor of both four-year and six-year graduation rates than are SAT/ACT test scores" which held for all of the public universities included in the study (Bowen, et al., 2009, p. 113). The specific numbers are given in Figure 1.

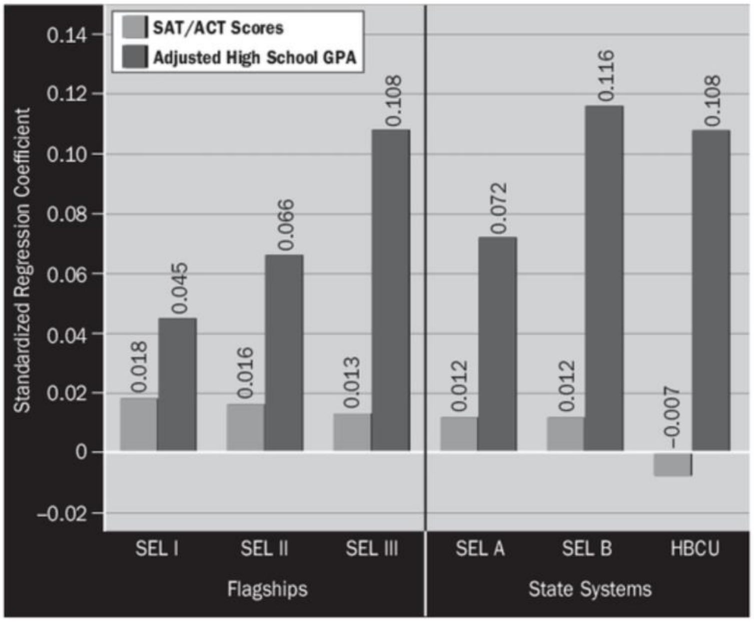

Figure 1. "SAT/ACT Scores and High School GPA as Predictors of Six-Year Graduation Rates, Standardized Regression Coefficients, 1999 Entering Cohort" where SEL refers to the selectivity cluster of the school. SEL I is the most selective and SEL III is the least selective for flagship universities, while A is the most selective and B is the least selective for state systems. HBCU under state systems refers to Historically Black Colleges and Universities. The higher the standardized regression coefficient the more closely correlated the data is with 6-year graduation rates, therefore, the larger value means the data is better able to predict 6-year graduation rates. Also, note that "the remaining incremental predictive power of the SAT/ACT scores disappears entirely when we add controls for high school attended, whereas the predictive power of high school GPA increases." (Figure 6.1 from Bowen, et al., 2009, p. 115-116)

What these standardized regression coefficients in Figure 1 mean specifically for the percentage of students who complete their degree in 6-years, is explained as follows. By increasing SAT/ACT scores by one standard deviation the 6-year graduation rates would increase by at most 2 percent, and for Historically Black Colleges and Universities

(HBCUs), this relationship was actually negative (Bowen, et al., 2009, p. 114). But, 6-year graduation rates would increase at higher rates when HSGPAs were increased. An increase of one standard deviation in HSGPAs were associated with "increases of more than 10 percentage points in graduation rates" at the least selective universities and 6 percent increase in graduation rates for mildly selective universities (Bowen, et al., 2009, p. 114). While the increase in HSGPA by one standard deviation does not have as large of an impact on graduation rates at the most selective public institutions (SEL I), the increase in HSGPA has still more than twice as large an impact as the same increase in test scores (Bowen, et al., 2009, p. 114). The results for "four-year graduation rates are very similar" with the only difference being that "both test scores and high school grades are stronger predictors of four-year graduation rates than of six-year graduation rates" (Bowen, et al., 2009, p. 114).

While the findings of Bowen, et al. are monumental, it must be noted that the data they used from 1999 was based on the SAT I, which was considered to be more of an aptitude test that could measure the ability of a student to learn rather than the more modern SAT II test. The ACT and SAT II tests are considered to be achievement tests, which are meant to more directly test the material that is taught in the classroom. However, other newer or more modern studies find similar results as Bowen, et al. In a study of 33 public and private institutions, Hiss and Franks found that a "student's academic performance in high school—not their test scores—best predicts postsecondary success" where success refers to graduation rates (Hiss & Franks, 2015, p. 34). In this case, "Students with strong high school GPAs generally performed well in college, despite modest or low standardized test scores" while "students with weak high school

GPAs—even those with markedly stronger test scores—earned lower college GPAs and graduated at lower rates" (Hiss and Franks, 2015, p. 34). With this data in support of HSGPAs as a better measure of college graduation rates and even college GPAs, inevitably people will wonder about how differences in rigor in various high school curriculums impacts these results.

In general, while there are differences in graduation rates predicted by HSGPAs from different high schools, HSGPAs are still better than ACT/SAT scores. Bowen, et al. found that "high school GPA is very positively and very consistently associated with six-year graduation rates *whatever the level of the high school that the student attended*" for data from North Carolina schools (p. 122). This means that even if you go to a high school that isn't as rigorous, a high GPA is still a strong predictor of college graduation. A more recent study using data from the Chicago Public Schools, which contains students from "neighborhood, magnet, selective, and vocational high schools between the years of 2006 and 2009" found that "HSGPAs perform in a strong and consistent way across high schools as measures of college readiness, whereas ACT scores do not" (Allensworth & Clark, 2020, p. 201, 209). In this study, college readiness was measured by 6-year college graduation rates. Of course, "HSGPAs are not equivalent measures of readiness across [different] high schools, but they are strongly predictive in all schools, and the signal they provide is larger than the differences across schools" (Allensworth & Clark, 2020, p. 209). Therefore, regardless of the differences in high school rigor, HSGPAs are still strong predictors of 6-year college graduation rates.

Allensworth and Clark also stated that although it is true that HSGPAs are based on "so many different criteria—including effort over an entire semester in many different types of classes, demonstration of skills through multiple formats, and different teacher expectations," this could actually be a benefit rather than a weakness (Allensworth & Clark, 2020, p. 209). HSGPA provides more of a long-term measurement for student achievement and effort, as well as how students are able to adapt to differences between teachers. These skills are important in college and life as well. On the other hand, ACT/SAT scores are one snapshot of a students' abilities conducted while they are under a strict time limit and covering material that may or may not closely resemble the students' current classes.

While the previous data used a general population, the trends of HSGPAs being strong predictors for graduation rates is also seen in STEM majors. A study on biomedical and behavioral science majors found that "students' SAT scores did not make a meaningful contribution to predicting persistence" in the major, but that "students' average high school GPA, the number of years they studied mathematics and biological science during high school, and institutional selectivity" at the college/university level did make a meaningful contribution (Chang, et al., 2008). In terms of institutional selectivity, it is proposed that the increase in selectivity of a university/college is linked to being more competitive or exclusive and therefore, feel less welcoming to underrepresented STEM students (Chang, et al., 2008). Another study that focused on STEM undergraduate completion found that HSGPA was the "strongest predictor of … completion of a STEM major" within 5 years, but that ACT scores and race were also significant predictors (Mau, 2016, p. 1498). This last note on how race was a significant predictor of STEM completion may be due to racial minorities not feeling welcome in

STEM (Urton, 2020). But, race is also important in the context of standardized tests, as different races and genders are known to score on average different from each other.

For the graduating class of 2016, there were a total of 2,090,342 students who took the ACT (ACT Inc., 2016, p. 8). Of those students the composite ACT score was lowest for Black/African American students and highest for Asian students (Table 1). This same trend is also seen for the ACT STEM scores, average of the Science and Mathematics sub scores, where Black/African American students score the lowest and Asian students the highest (Table 1). These racial/ethnic differences are also seen with the SAT. Reeves and Halikias found that the average SAT math scores were 428 for blacks, 457 for Latinos, 534 for whites, and 598 for Asians, with black and Latino student scores "clustered towards the bottom of the distribution" based on 1.7 million students who took the SAT in 2015 (Reeves & Halikias, 2017). These two studies do not control for the effect socioeconomic disparities on racial inequities in ACT and SAT scores; however, there is data to suggest that socioeconomic differences may not be able to explain the racial differences in test scores. The Geiser study found that "racial and ethnic group differences in SAT scores are not simply reducible to differences in family income and parental education" using data from "California residents who applied for admission to the University of California from 1994 through 2011" (Geiser, 2015, pp. 1, 4).

Using data from all high school seniors from 1999 who took the SAT in North Carolina, the researchers found that "race and SES [socioeconomic status] are more highly correlated with SAT scores than with high school grades" where SES includes parental education and family income (Bowen, et al., 2009, p. 126). Also, SES "prove(s)

Table 1. Average ACT Scores by Race/Ethnicity for the graduating class of 2016. (ACT Inc., 2016, p. 8)

Race/Ethnicity	N	Percent	English	Mathematics	Reading	Science	Composite	STEM
All students	2,090,342	100	20.1	20.6	21.3	20.8	20.8	20.9
Black/African American	272,363	13	15.8	17.0	17.4	17.2	17.0	17.3
American Indian/Alaska Native	16,183	1	16.3	17.7	18.2	18.1	17.7	18.2
White	1,119,398	54	21.9	21.7	22.8	22.1	22.2	22.1
Hispanic/Latino	337,280	16	17.6	18.8	19.2	18.9	18.7	19.1
Asian	93,493	4	23.3	25.0	23.7	23.6	24.0	24.6
Native Hawaiian/Other Pac. Isl.	6,797	0	17.4	18.9	18.9	18.6	18.6	19.0
Two or More Races	85,494	4	20.4	20.5	21.6	20.9	21.0	21.0
Prefer not/No Response	159,334	8	19.3	20.0	20.6	20.0	20.1	20.3

to be statistically significant predictors of SAT scores on an ‘other-things-equal’ basis” (Bowen, et al., 2009, p. 126). This is far from the only research to come to this conclusion. Another study also found that the ACT was racially and socioeconomically biased, where white students and those who come from wealthier families scored higher (Evans, 2015). Since it is widely recognized that it is difficult to get into a college or university where the average SAT or ACT score is much greater than the applicant’s, it is worrisome how much weight colleges and universities put into these scores when making admissions decisions, because they may be exacerbating socioeconomic and racial divides. This is also extremely concerning because a good education can help bridge these gaps.

However, we do not see these racial and socioeconomic status disparities as much in HSGPA data. Bowen, et al. found that HSGPAs are “invariably stronger incremental predictors of six-year graduation rates than are SAT/ACT scores, across all categories of race/ethnicity, gender, and SES” (Bowen, et al., 2009, p. 125). Given the data that HSGPA are better predictors of degree completion, even specifically for STEM majors, regardless of race and SES, it seems unnecessary to continue to use SAT/ACT scores to attempt to predict college graduation rates. This makes SAT/ACT scores obsolete for admissions benchmarks, which are used to determine if a student is prepared for college.

The Thomas study noted that in 2001 the FairTest.org group listed only 391 colleges and universities, most of which were less selective institutions, that deemphasized or did not require SAT/ACT scores in making their admissions decisions out of about 1,650 accredited four-year colleges” (Thomas, 2004). However, the newer studies and controversies surrounding the ACT and SAT being used in college admissions has led to an increased interest in getting rid of these exams. To understand the impact of requiring versus not requiring test scores, universities and colleges have chosen to start pilot studies at their specific school by becoming test-optional to see if they would receive more diverse applicants and ultimately help decrease one of the barriers certain students face while applying to college.

A previous study on the effects of test-optional policies on student demographics found that of 33 public and private institutions 37,000 out of 123,000 students and alumni were accepted into college without submitting test scores (Hiss and Franks, 2015, p. 33). Of these 37,000 students who did not submit a test score, the researchers found that these students "were more likely than submitters [those who submitted a test score] to be first-generation-to-college enrollees, minority students, Pell Grant recipients, and women" (Hiss and Franks, 2015, p. 33). Therefore, without test score requirements, universities are able to recruit more diverse candidates, which is important to help decrease socioeconomic and racial barriers to higher education.

Of course, while these policies help increase diversity, the next question some ask is if students who don't submit test scores are able to do as well in college as those who submit test scores. Again, this concern is largely due to the ever present insistence that standardized tests are the best predictor for college success, however broadly defined. But Hiss and Franks (2015), found that submitters and non-submitters did equally well in college. "Specifically, non-submitters earned cumulative GPAs that were only .05 points lower (2.83 versus 2.88) than submitters; the difference in their graduation rates was 0.6 percent (63.9 percent versus 64.5 percent). By any standard, these are trivial differences" (Hiss and Franks, 2015, p. 33).

Based on this current data, more colleges have started to become test-optional or test-blind. With the 2020 COVID pandemic, many testing centers closed down and/or pushed back test dates. In response, universities and colleges waived the ACT and/or SAT requirement as a way to ease the burden on students who had no control over these closures and cancelations. While final data on the future of students who did not submit a test score for fall 2020 is as yet unknown, some of the universities and colleges who chose to waive the ACT and/or SAT requirement for the first-time last year have continued these policies.

Currently, there are more than 1,365 accredited, 4-year colleges and universities throughout the United States that have some sort of ACT/SAT test optional policy (https://www.fairtest.org/university/optional). While some universities and colleges have completely gotten rid of these test requirements, others have chosen to deemphasize the scores in their admissions process by only using it for academic advising and placement, or only requiring it when minimum grade-point average and/or class rank is not met (https://www.fairtest.org/university/optional). Especially as more data comes in on the graduation rates (or other measures of success) for students who were admitted without submitting test scores during the COVID pandemic, we will likely see a continued trend in the decrease in standardized testing requirements for college/university admittance.

CHAPTER FOUR

Transition from High School to College STEM Courses Teaching

Often the first and second year of college are difficult for students, and this is usually due to the drastic differences in expectations between high school and college level courses. The first two years of undergraduate courses are when the majority of students leave their science major (Gasiewski, et al., 2011). This is not uncommon and has been noticed for years. Part of the reason for this is the lack of connection between K-12 education standards and those present at the college level. K-12 education is often highly regimented by political policies that can change as politics change. This is seen in chapter two with the large effects the NCLB policy had on the structuring of K-12 science education, especially high school education. But, "state legislatures and governors often view higher education (college) as comparatively untouchable" (Kirst & Venezia, 2001, p. 93). There is often little discussion between high schools and colleges beyond recruitment efforts. Therefore, high schools can be left in a difficult position of trying to prepare students for a college situation that is lacking a strong national standard. Arguably, though, this effort should not just be a burden on high school education but should elicit changes at the college level, too.

This difference in expectations can cause students to need remedial college courses. At South Dakota colleges, students must take remedial courses in order to meet the basic level of understanding in course material, usually mathematics or language arts, required for college courses. These classes often cost students "about $1,000 per class and provide them with no college credit" (Pfankuch, 2019). The number of students required to take these classes is also quite high. "Every year, about 30 percent of South Dakota high school graduates who enroll in a state university must take remedial courses in math or English because they don't test high enough in those topics" (Pfankuch, 2019).

This is not drastically different from other states. The California State University system in 2000 had 46% and 45% of its students not able to meet the standards in reading/writing and mathematics, respectively (Kirst & Venezia, 2001, pp. 94-95). As students struggle to ‘catch-up’ with their counterparts, the style of college teaching may also be alienating, particularly for STEM students.

While students are struggling to perhaps gain the educational foundation that they are expected to have going into their college STEM courses, they are also faced with a new environment and more responsibility to learn the material on their own. As I have discussed with current University of South Dakota STEM students, in rural high schools, the smaller class sizes allowed teachers to know them on a more personal level. Therefore, the teachers seemed to know who was struggling and could more directly help the student(s). Or, if the whole class was struggling with certain concepts, the teacher may have readdressed the material with the whole class. However, when students get to college, professors often leave the responsibility of learning the material to the students. Especially for introductory courses, professors have a lot of material that they intend to cover.

As previously discussed in chapter two, standardized tests are causing middle and high school science teachers to restructure their curriculum into less engaging approaches, such as lecturing, and relying heavily on memorization. Introductory science courses are notorious for relying on “large lecture-based courses and lack of engaging pedagogy” because it is an easy way to cover a large amount of content with a large audience (Gasiewski, et al., 2012, p. 230). As noted by previous studies in chapter two, the lecture-based format promotes “memorization over conceptual understanding”

(Gasiewski, et al., 2012, p. 230). While the teacher-centered teaching style induced by standardized tests functions as a barrier to effective science education in high school, the dependence on this style of teaching in introductory science courses may also serve as a barrier to incoming students, especially, since students are expected to know the material covered in their introductory STEM courses at a much higher level of detail than they likely were expected to know in high school. Introductory college STEM classes are spent with professors lecturing to students, while the actual consolidation and understanding of the new concepts must come from the students' own drive to learn the material. Often if a student is having difficulty understanding the concepts in a college course, they have three main options: go to the professor, discuss with a friend/study group, or search online.

As a freshman, it can be daunting to go to a professor that you don't really know and ask them to re-explain certain concepts. Depending on how that interaction goes, sometimes students end up leaving more confused than when they went in, and a student may not try to go to the professor for help again. This leads to a stressful situation where having a group of friends/study group in a class or even watching informational videos online can be particularly beneficial, because other people may be able to explain the material in a more understandable way than the professor. However, for new students, if they have not found a group of people to study and discuss class material with, their only option left is to attempt to understand what they do not know through information online. This can make learning new material and adjusting to the increased demands of college professors difficult and unwelcoming.

As students transition from high school, it can be challenging for them to assimilate into college and become responsible for learning the material themselves and seeking help if they need it. However, feeling comfortable even discussing with faculty or other students about needing help may be difficult. Certain students are able to do quite well in high school courses with little external learning/studying, but in college, it is imperative that you study and learn the material. Therefore, it may take a while until students understand when they need to go get help. But, with the especially cold STEM environment, students may feel that if they have to ask for help then they are not cut out to be in science. "The culture of science says, 'Not everybody is good enough to cut it, and we're going to make it hard for them, and the cream will rise to the top'" (Epstein, 2006). Often this sentiment, used to describe specific courses, is referred to by students and faculty as "weed out classes," where students may feel like gladiators in Roman battles that must fight for the right to even be *considered* for a part in the scientific community. This unwelcoming style and environment are so pervasive that it is usually verbally acknowledged in introductory STEM courses.

Based on my discussions with STEM majors at several universities, many STEM students have sat through the first day or week of class being reminded by professors that at least half of the students who are currently sitting in the room will not make it to graduation with their current STEM major. This sentiment is repeated verbally in multiple STEM introductory courses throughout this first week of at least the first year of classes, but sometimes the second year as well. At times, this speech is even given during the semester, sometimes after a particularly bad exam that many students did poorly on. This serves as a mantra of sorts that does little to encourage students to challenge themselves and grow in the face of their difficulties but may instead cause students to question why they are in STEM.

It is extremely common for introductory science courses to be labeled as weed out classes. In organic chemistry, a (nationwide) notoriously difficult class that is known for its reliance on student memorization, professors may even boast about low passing rates or how enrollment in further science courses drop dramatically after students go through their class. The cut-throat scientific environment in general can also be disarming for students, and it is even more intense at more selective institutions (Chang, et al., 2008). “Thus, students who attend more selective institutions are at greater risk of not persisting in their science major” where selectivity is determined by the average combined SAT score of the incoming class (Chang, et al., 2008). However, students who leave science after these weed out courses “are not noticeably poorer students than those who stay” but are often female and underrepresented minority students (Pfatteicher, 1999, p. 295). This trend of females and underrepresented minority students leaving at higher rates is still seen today and continues to impact the diversity issue in STEM.

In 2013, a study of students who entered into STEM majors between 2003 and 2009 found that 48% of bachelor’s degree students and 69% of associate’s degree students left the STEM field by the spring of 2009 (Chen & Soldner, 2013, p. 6). “Roughly one-half of these leavers switched their major to a non-STEM field, and the rest of them left STEM fields by exiting college before earning a degree or certificate” (Chen & Soldner, 2013, p. 6). Within the percentages of switchers, many of the students are underrepresented in STEM, causing STEM to lose diverse talent that is sorely needed. There is a large disparity between racial groups in STEM completion rates (Theobald, et al., 2020). Currently, “52% for Asian Americans and 43% for Caucasians [versus] 22% for African Americans, 29% for Latinx, and 25% for Native Americans” complete their STEM degrees within 6 years (Theobald, et al., 2020). Sadly, “Racial and poverty gaps in STEM college and careers begin before college” (Glennie, et al., 2019, p. 232), which may in part be due to unequal education systems. For example, in New Orleans in late 2010, “4% of students in New Orleans public schools [were] White and 2/3 of those students attended three publicly funded, selective admissions schools with per pupil expenditures substantially greater than other schools” (Parsons & Turner, 2014, p. 107). Therefore, most of Black and other minority students in New Orleans were going to schools that were less well funded than white students. This could have a large impact on the quality of teaching students receive as well as the access they have to higher level science courses.

There is also a disparity in the number of women who obtain STEM degrees. While women earned approximately 57% of bachelor’s degrees in 2013-2014 (National Center for Education Statistics, 2017), during that same time, women earned only 29% of STEM bachelor’s degrees (National Student Clearinghouse, 2015). Glennie mentions that the loss of women at the college and university level may instead be due to “the absence of female role models, the perception that STEM curricula are irrelevant, and feeling unwelcome in STEM courses” (Glennie, et al., 2019, p. 232). In general, the issue of diverse role models, lack of student interest, unengaging teaching styles, and the chilly environment of STEM at the university/college level are likely key components to STEM losing its diverse talent.

CHAPTER FIVE

How Teaching Style Can Impact STEM Education

Due to the increased rates of minority students and women dropping out of STEM majors and the negative impacts standardized tests can have on these groups, science educators and researchers have been developing and implementing different programs to reduce this loss of talent. Most of these STEM programs and/or pedagogical changes are occurring at the high school or pre-college level. One program, called a STEM bridge program, is designed as a summer program for underrepresented students. Each STEM bridge program is slightly different, but overall the goal is to help students understand, prepare for, and be excited about a STEM degree as they start their undergraduate education in the fall. For example at the Xavier University of Louisiana, the STEM bridge programs are designed to strength students' math and science skills and to "teach students to apply their new skills in collaborative study groups and authentic laboratory settings" (Witt, 2015). These programs, directed particularly at minorities and women, have increased the number of students interested in STEM careers at the beginning of college compared to those not in the program (40% versus 24%, respectively) (Kitchen, et al., 2018, pp. 698-715). They have also received positive feedback from students, where 60% of participants reported an increase in "knowledge, skills, and information related to STEM fields" (Kitchen, et al., 2018, pp. 698-715). These programs allow students to be in a more collaborative environment and really engage in the material/concepts rather than just memorizing more facts.

Currently, some high schools are being redesigned as STEM high schools by following "specific design principles or us[ing] innovative teaching methods to promote subject matter engagement" (Glennie, et al., 2019, p. 229). The goal is to better prepare students at the high school level in science and math courses so they are better equipped to succeed in a STEM degree in college/university. The innovative teaching methods that these STEM high schools focus on are "inquiry-based learning, project-based learning, and problem-based learning, which give students the opportunity to engage in integrated, complex learning activities" (Glennie, et al., 2019, p. 229). After matching/controlling for location, percentage of minority students, and other factors, a study found that STEM high schools "had higher rates of passing an advanced mathematics, advanced science, technical science, or engineering course" than those at traditional high schools (Glennie, et al., 2019, p. 249). Also, "students in groups typically underrepresented in STEM [racial minorities, women, and those from low socioeconomic groups] gained a greater benefit" from these STEM high schools (Glennie, et al., 2019, p. 250). However, this study only looked at learning outcomes at the high school level, and they did not investigate if this increase in STEM preparation in high school increases the number of students interested in STEM degrees and their rates of college/university graduation with STEM degrees. But, their finding that better STEM teaching methods at the high school level help underrepresented students do better in STEM courses is extremely important.

Focusing on more interactive learning techniques, which could help to create a more supportive and inclusive environment, is a more effective way to decrease the gap between overrepresented and underrepresented students than focusing on standardized test scores that are weak predictors of student graduation rates. Research has shown some variation in efficacy of active learning, but Theobald, et al. propose a "heads-and-hearts hypothesis, which hold that meaningful reductions in achievement gaps only occur when course designs combine deliberate practice with inclusive teaching" (Theobald, et al., 2020). One educational structure for improving active learning is to develop questions and activities that adhere to Bloom's taxonomy, which was originally published in 1956 as a way to help college professors prepare their annual comprehensive exams (Krathwohl, 2002). More recently, Bloom's taxonomy has undergone some minor changes (Figure 2), but is widely used in Supplemental Instruction (SI) as a way to cultivate more active learning.

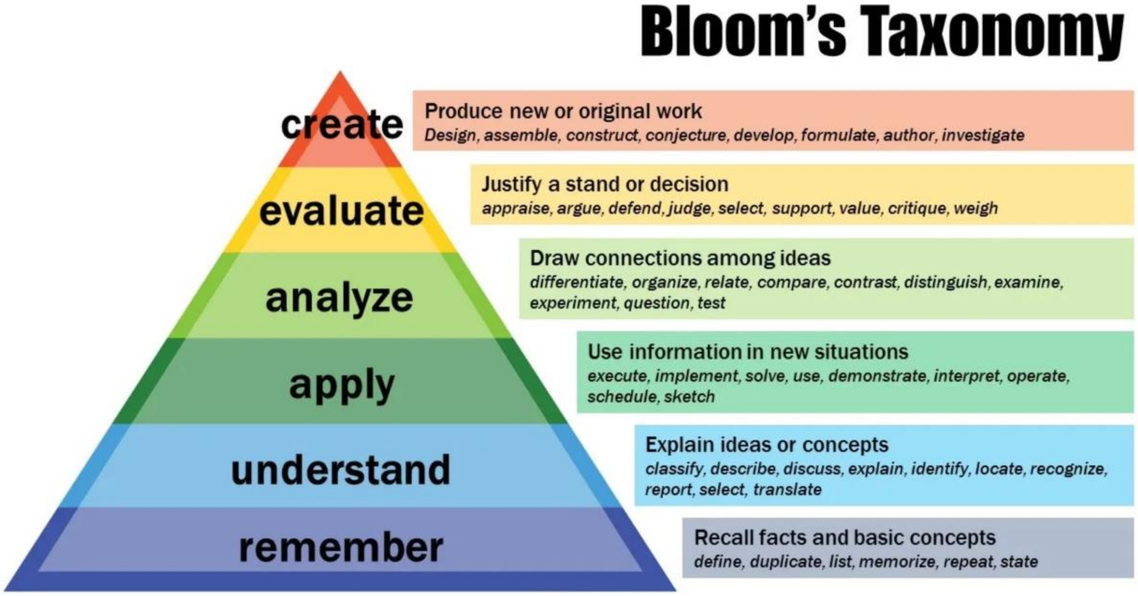

Figure 2. The revised or newer version of Bloom's taxonomy that is used in education (Retrieved from https://fresnostatesiguide.com/blooms-taxonomy/). Bloom's taxonomy is included in the training for Supplemental Instructors here at the University of South Dakota, where this tool is used by Supplemental Instructors as a way to build sessions that lead to student interaction/engagement and helps students learn the material at a deeper level.

The goal is to form questions that lie within each of the layers and have students individually or as a group respond to the various questions. During class, instructors lead the discussion or questions in a way that builds students up through Bloom's taxonomy levels. For example, asking students to *evaluate* what would happen in a complex system if a certain protein was not present or having students *create* their own experiment to test a hypothesis, would require students to be at the highest learning levels. This form of directed learning, from single basic concepts to questions that rely upon multiple concepts, requires student participation to be beneficial.

SI is "an academic support program that employs successful later-year tertiary students to facilitate peer-learning sessions" and is usually provided for class that have high rates of students obtaining a D or F grade or withdrawing from the course (Dawson, 2014, p. 609). SI has a multitude of data to support its usefulness, but SI can be used for both STEM and non-STEM courses. However, Georgia Gwinnett College (GGC) adapted the general SI concepts specifically for their STEM classes where their goal was to create "a culture of collaborative learning that supports students in the transition from high school to college-level STEM education" and had beneficial results (Achat-Mendes, et al., 2019, p. 18). Notably, GGC is an extremely diverse institution where "Approximately 60% of the 12,000 GGC students identify with a racial or ethnic minority … [and] Over 50% of students are first-generation college students, 33% are part-time students, 32% work twenty or more hours/week, 78% receive some form of aid, 52% are eligible for Pell Grants, and 14% of students are non-traditional" (Achat-Mendes, et al., 2019, p. 14). Therefore, their findings are crucial to realizing that strong teaching/learning techniques and a supportive environment can help all students, but especially underrepresented STEM students, better succeed in STEM.

The study of the adapted GGC SI program found that there was an "increasing trend toward a greater percentage of students earning A's and B's as the frequency of session participation increased" which has also been found in other studies on the general SI program structure (Achat-Mendes, et al., 2019, p. 17). Specifically, it was found that "of the students who attended 10 or more PSI sessions, 38% earned As while 13% earned DFW grades and conversely, of the students who attended one or two sessions, only 17% earned As while 36% earned DFW grades" (Achat-Mendes, et al., 2019, pg. 19). PSI refers to the acronym that GGC gave to their adapted SI program and DFW rates are the percentage of students who receive a D or F grade or those who withdraw from the course. Of course, if only students who received As in high school or had a strong academic backgrounds attended these sessions, this positive result could simply be due to a population that is biased towards a positive relationship. However, the researchers found that "high school GPA [was] not a good predictor of participation in the PSI program" (Achat-Mendes, et al., 2019, p. 19). Also, attending more SI sessions had a larger positive effect on the final course grade of students who had lower HSGPAs than those who had higher HSGPAs (Achat-Mendes, et al., 2019, p. 17). This means that students who were less prepared for the rigor of college-level STEM courses had a larger benefit from attending these SI sessions, which could help close the gap between overrepresented and underrepresented STEM students. This is an especially important result since the average entering freshman class at GGC has a HSGPA of 2.2 on a 4.0 scale and the "percentage of students earning failing grades (DFW rates) for introductory courses in many majors in Science, Technology, Engineering, and Mathematics (STEM) are consequently high, ranging from 24 – 39%" (Achat-Mendes, et al., 2019, p. 14). To get more students, especially underrepresented students, more interested in STEM, retain students in STEM majors, and increase graduation rates of STEM students, a key ingredient is teaching at the high school and college/university level. The President's Council of Advisors on Science and Technology has even recommended improved teaching techniques as a way to increase the number of STEM degrees completed (President's Council of Advisors on Science Technology, United States, & Executive Office of the President, 2012). Currently, actively engaging with students is the pinnacle of more effective teaching.

Actively engaging students is referred to as active learning, where teachers ask questions of their students or have students work through problems in groups. This process of engaging students in higher levels of learning occurs in SI and can be achieved by using Bloom's taxonomy as previously discussed. A meta-analysis of 225 studies that compared student performance in undergraduate STEM courses that used either traditional lecturing or active learning teaching styles found that active learning was an improved teaching technique. Active learning decreased average failure rates by 55% from traditional lecturing styles, where "(a)verage failure rates were 21.8% under active learning but 33.8% under traditional lecturing" (Freeman, et al., 2014). Student achievement was also higher for both instructor-written course examinations as well as performance on a concept inventory in the active learning groups compared to the traditional lecturing (Freeman, et al., 2014). These improvements were not confined to only small classes or those at a certain academic level, as increases in student achievement were seen “across all of the STEM disciplines and occur[ed] in all class sizes, course types, and course levels” (Freeman, et al., 2014). While this study found that active learning can improve all students’ learning and grades, others have shown that this style of teaching has an even larger positive effect on underrepresented students.

A study found that active learning, compared to lecture only teaching, reduced achievement gaps between overrepresented peers and underrepresented minorities by 33% for course exams and 45% in passing rates for all STEM courses (Theobald, et al., 2020). They also saw an overall increase in achievement and passing rates (Theobald, et al., 2020). While the study did not look at how active learning impacted underrepresented minorities graduation rates, it is likely that this change in teaching style would lead to more underrepresented students graduating with a STEM degree. Most STEM introductory courses require students to achieve a C or better to continue in the major, but underrepresented students have grades that average in the “C range—putting many at high risk of not meeting the threshold to continue” (Theobald, et al., 2020). Therefore, “even a small increase in examination scores can lift a disproportionately large number of URM [underrepresented minorities] and low-income students out of the danger zone where they are prevented from continuing” (Theobald, et al., 2020). By focusing on more active learning techniques, teachers could help minority students be more successful at the beginning of their science careers and provide them with a strong foundation so they can continue to be successful in a science career.

It is unknown exactly why active learning “disproportionately benefits students from underrepresented backgrounds” (Urton, 2020). However, Theobald commented that the active learning techniques “could create a more welcoming and inclusive environment, which may be especially important for students who often feel as if they don't belong in STEM, or feel excluded"' (Urton, 2020). This is particularly important since underrepresented students tend to leave STEM majors at higher rates as previously discussed in Chapter 4. Ultimately, improved teaching of STEM courses may provide students with the confidence and reassurance that they need to succeed in STEM. In the adapted SI program, "70% of participating students believed that PSI helped them improve study skills, course content, and confidence in their abilities to participate and achieve their goals in STEM courses" (Achat-Mendes, et al., 2019, p. 17). Also, as Theobald, et al. argue, support is an important aspect of helping students to reach their educational goals (Theobald, et al., 2020). By improving teaching of the STEM courses themselves and continuing to use these same teaching techniques in peer led SI sessions, we could help students' achieve better grades in STEM courses and feel more welcomed in STEM, thereby ultimately increasing the diversity in STEM.

To engage students in large (or small) lecture halls, professors have several ways they can implement a more active learning style of teaching. For example, in organic chemistry, while many of the chemical reaction pathways must be memorized, a professor can intersperse questions on material that was just covered in the previous slides. During a lecture on SN1 and SN2 reactions, he/she could put the chemical reactants on the board and have students work through the problem on their own before comparing their answers with those around them. This provides students with the opportunity to apply the information that they just saw. If a student is confused, it also allows them to actively discuss with those around them during class, where another student may be able to help them get the clarification they need. The professor then could either ask for a volunteer to come up to the board and write out what they got for the answer or, depending on the feasibility of that, the professor could work through the problem after the class finished working through it. This allows a group of students who may still be confused after discussing with each other to see the problem worked out and explained. A professor can go a step further and ask for non-verbal feedback on how students did or felt about the question, such as asking for head nods to confirm that the worked out problem made sense. If not, the professor can choose to briefly summarize the new material, go through how to get the answer again, or pose a second similar question to the class.

Providing students with the time to work through the problem on their own, with the professor still present if they have any major difficulties, requires the students to address what they know or do not know. Then, being able to share their thoughts with each other allows for collaboration, something that is quite common and useful in the professional STEM field, but can also lead to outside of class study groups. If a student does not know anyone in the class, it may be difficult to set up an outside of class study group. But, through the sharing of answers with those around them, they may become more familiar with several students and feel comfortable studying together. This also helps build camaraderie among the class when they work through problems together, because they are all working towards the same collective goal – to learn the new material and do well in the course.

This structure of posing questions can come in a variety of different formats depending on the type of STEM class. Professors can provide students with multiple choice or true/false questions on the material to check understanding in perhaps more concept-based classes. In chemistry, physics, and some biology courses that include math-based problem solving, professors can provide those types of questions and allow students to do the calculations in class. For example, in genetics, students may be asked to determine the probability that a child in generation four of a pedigree will inherit the disease. This type of question requires students to first determine the inheritance pattern of the disease based on the pedigree information and then apply those corresponding concepts to how they must approach setting up and solving the math problem.

Ultimately, the key is that the professors require students to engage with the material and each other. In doing so, this helps to build the relationship among students and between students and the professor, so students may feel more comfortable asking for help and/or help decrease the feelings of inadequacy that students may have if they are having difficulty understanding the material.

> Active learning may also help students comprehend material better by taking them through complex concepts step by step, with regular check-in moments. This targeted, intensive practice may disproportionally help students from educationally disadvantaged backgrounds, by ensuring they understand the material and don’t fall behind. (Urton, 2020)

Everyone has difficulty with STEM concepts/problems at one point or another, but having a community to engage with and learn from can be the difference in choosing to leave a STEM degree and completing one.

CHAPTER SIX

Conclusion

Changing how we teach STEM courses from K-12 to undergraduate, can have a larger positive impact on more students, most notably those who are underrepresented in STEM, than focusing on standardized test scores. It is important that students have a positive exposure to STEM during their K-12 education, to potentially increase their interest in a STEM degree. However, our current focus on measuring success through standardized tests at the K-12 level has put extreme pressure on teachers to prepare their students for these tests. This has the negative side effect of teachers modifying their class content to be more focused on the tests and to teach the material in a disconnected way. Teachers also start to implement more lecture-based teaching to cover as much potential test material and needed testing techniques as possible in a short time frame. However, these changes decrease student engagement in the class and push them to memorize facts rather than connecting the material and concepts to each other, which is important in understanding and utilizing their STEM knowledge in the future.

Lecture-based teaching is also common in introductory STEM courses at the college/university level for the same reasons. The chilly environment and teaching structure of these undergraduate STEM courses alienates many students and causes high attrition of STEM students within their first two years. The number of students leaving STEM degrees is also disproportionately underrepresented students, specifically women, racial/ethnic minorities, and those from low socioeconomic backgrounds. Science thrives on new and unique concepts; therefore, it is important to retain these diverse students, as having a more diverse base of scientists opens up the potential to have more innovation.

The SAT and ACT are known to be racially and socioeconomically biased and do not predict college graduation rates reliably. Still, while the number of institutions requiring test scores is decreasing, many institutions continue to make acceptance decisions based on these scores. This can decrease an institution's ability to attract qualified underrepresented students. HSGPA is a stronger predictor of graduation rates. HSGPAs do not have the same racial and socioeconomic discrepancy issues that the ACT and SAT scores do, and students who have high HSGPAs but low test scores are able to do just as well in college as students with high HSGPAs and high test scores. Given that a college degree has a much larger impact on a student's job and earning potential than having several college credits and no degree, it seems that colleges and universities would be better served by focusing more on the student's academic history than on a standardized test score.

As a way to diversify STEM and to better retain our talented students, researchers have studied the impact of different programs and pedagogical changes. Ultimately, the most effective way to retain and interest students in STEM is to teach them in more engaging ways at the K-12 and undergraduate levels. Active learning can be used in both the class setting and peer led sessions to engage students with the class material. This process helps students to learn the material at a deeper level and to think more critically about the material they are learning. It also helps to decrease the achievement gap between overrepresented and underrepresented students. Helping all students engage more with the material and to form a friendlier, more welcoming environment has the potential to greatly improve the outlook of STEM graduation rates.

Ultimately, as scientists and researchers, we want to interest students in STEM and retain them. To do so, we must be cognizant of the barriers that our current requirements pose to students and work to make STEM more accessible, specifically, the barrier and challenge that standardized tests pose to better STEM education. We need to move away from our heavy use of standardized tests and instead work towards more active learning and engaging teaching styles. By providing students with a supportive and enjoyable STEM learning experience, we have the potential to make STEM more welcoming to a more diverse population and to develop stronger scientists.

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