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Making STEM Equitable: An Active Learning Approach to Closing the Achievement Gap

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Abstract

Active learning is a pedagogical approach which engages students in the learning process, aiming to optimize comprehension of educational material. Meta-analysis of current research shows maximum impact when applied to STEM education, especially for underrepresented minority (URM) students and students with a low GPA. This study focuses on student success, progression, completion and STEM interest within the General Chemistry course sequence at Blinded City College, which has a 51% Hispanic student population. Data from classes implementing active learning pedagogy consistently had higher success and progression rates, as well as increased progression success from General Chemistry 1 to General Chemistry 2, with a greater positive impact and completion success among Hispanic students compared to students from Asian populations, whose progression success was negatively impacted through use of active learning pedagogy in comparison to traditional lecture-based coursework. Comparison of scores for the American Chemical Society General Chemistry Exams, from this community college and at a national level, indicates active learning students perform equally well on chemistry standardized tests. In total, active learning classes were most beneficial to Hispanic students, and should be designed according to course level, be scaffolded to future coursework to maximize impact through development of STEM active learning pathways in which students are immersed in active learning classrooms continuously through undergraduate STEM academic coursework.

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INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education in the United States has transitioned through various iterations of pedagogical themes, with the aim of increasing effectiveness of STEM teaching. Though these ever-evolving programs have kept STEM education in constant flux, each successive development has focused on quantifying teaching effectiveness with implementation of modern pedagogy to increase student learning (Lamb 2015). The most prominent of these pedagogical shifts has been towards utilization of student-centered active learning strategies as opposed to traditional, teacher-centered instructional approaches. This shift is at the forefront of optimizing instruction to maximize student success (Schmidt 2011; Kerrigan 2017).

Active learning became a central topic of educational research during the 1960's and has been one of the few educational curriculum innovations to survive that period (Schmidt 2009). Initial resistance from educators using the more conventional lecture-based instruction inhibited widespread implementation. Over time however, active learning has gained traction and evolved into an educational community of practice (Tight 2019).

More recent research has moved towards diversified study of variables, to determine not only the success of active learning, but which strategies ought to be utilized for maximum impact within the educational community. Such strategies involve increasing instructor awareness and classroom adoption of research-based learning styles (Vanderlinde 2010), building rooms that optimize active learning in-class experiences (Foote 2014) and dissemination of best practices for implementation (Eddy 2017). It is commonly accepted that reform in education should come primarily from evidence provided by research. However, despite offering many of the solutions to a somewhat stagnant educational system, the gap between research and practice remains a major issue (Furman 2019; Gibbons 2018; Broekkamp 2007). Most instructors are resistant to change, preferring traditional methods over-active learning, which has proven to be an effective teaching strategy (Terhart 2013).

As active learning has gained attention and growing popularity, much of the debate has centered around its value within STEM education. One question has become whether active learning improves success and retention in the classroom at the expense of academic rigor (Omelicheva 2008). It is true that "active learning" is a blanket term, and may be implemented in distinct ways, thus including room for course and instructor specific implementation. This has the advantage of being a dynamic type of learning where students intensely interact with each other, with education materials, and with teachers (Demerci 2017). Due to the nebulous nature and definition of active learning, the variety of techniques examined thus enables the wider community to determine which, among the many practices, has proven most successful for educators' distinct disciplines and courses. Among this number is found problem-based learning (Marra 2014), and flipped classroom practices (O'Flaherty 2015), in which failure rates for STEM classes decreased by 55% and are accompanied by higher letter grades (Freeman 2014).

Implementation of an active learning approach in engineering and introductory statistics courses made use of portfolios so that students might easily keep track of their work over the semester. This minimal alteration led to in-class improvement and a more positive view of engineering (Adair 2018). Feedback from students in an animal physiology class at the University of Pittsburgh showed active learning increased enjoyment and engagement, leading to higher exam scores as compared to those from a lecture-based version of the same course (Minhas 2012). Furthermore, a study consisting of 222 third year medical students at Rheinisch-Westfälische Technische Hochschule University tested four subgroups of learning: E-learning, Lecture, Seminar Groups, and self-instructed. The study concluded self-instruction and E-learning outperformed lecture based and seminar-based classrooms (Peine 2016). Active learning promotes actively engaged classrooms, where students become critical thinkers, and apply what they learn to real world scenarios, performing activities which are engaging both intellectually and somatically (Owens 2017). It has been a powerful pedagogy in closing the achievement gap between underrepresented minority (URM) students and non-URM students (Ballen 2018).

Student demographics at universities are becoming more ethnically diversity with larger numbers coming from low socioeconomic groups (University of California 2019). Unfortunately, growing diversity at a university level does not reflect a trend of the same magnitude within the STEM pathways. A study tracking freshman minority STEM students found that by their senior college year 50% had changed their major (Herrera 2011). Hence, a Joint Working Group was convened by the National Institute of General Medical Sciences and Howard Hughes Medical Institute to recommend solutions to increase success and retention in URM students in STEM (Estrada 2016). Five strategies were proposed. One, “Unleash the power of the curriculum” encourages course-based undergraduate research experiences (CUREs) and infusion of inquiry-based learning pedagogy into STEM course material. These teaching strategies have been successfully embedded into undergraduate STEM curriculum (Linn 2015). In a studio-based General Chemistry course, students from underrepresented backgrounds had a 0.58 grade increase in chemistry GPA compared to those in traditional lecture/lab combination (Greco 2018). Utilization of CUREs have made access to the scientific community more inclusive and broadens the range of students participating in research, opening the door for students who need it the most (Bangera 2017). An active learning approach allows all students, URM included to engage with instructors, which promotes a sense of belonging in the classroom and decreases alienation a student might feel, an issue especially prevalent with women of color (Moller 2019).

Active learning is a valuable option in teaching but must be utilized to enhance the student learning experience. When using active-learning techniques in introductory biology course researchers found no association between active-learning exercises and amount students learned (Andrews 2011). Instead, they discovered a positive correlation between student learning and explanation of common misconceptions; they suggested use of active learning to change misconceptions specific within the class. In this case, active learning was shown to be especially useful for full comprehension of course material. This example is an indication that active learning must be employed only where it is just as or more successful than traditional lecture. It must also overcome inherent obstacles to implementation, such as cost, while working to dispel the feeling of anxiety experienced by students not familiar with active learning approaches. (Hyun 2017). While significant however, these roadblocks pale in comparison to resistance by instructors, who are far more comfortable with the status quo of lecture-based instruction, than are actively engaged in an evolving educational system.

Rather than a complete overhaul of lecture-based instruction, infusion of active learning within a STEM course allows for both traditional and active learning-based teaching styles to retain their strengths and advantages (Minhas 2012). Effectiveness in adopting active learning pedagogy such as SCALE-UP (a widely disseminated program meant to increase construction of active learning classrooms, buildings, and adoption of teaching practices) is most dependent on developing a coordinated approach within a STEM academic program as opposed to an individual class. The goal of widespread implementation can be accomplished via infusion of active learning within a more traditional STEM course setting. In this manner, increased faculty participation in active learning may be utilized to enhance a STEM course as opposed to full implementation, leading to an increase in STEM classes within an academic pathway in which students benefit from components of active learning pedagogy thus, working to steadily shift educational practices towards active learning.

This study will discuss best practices as part of the larger active learning methodology implemented in a sequence of general chemistry courses at a majority Hispanic community college, using comparative analysis of URM and non-URM student retention, success, progression and completion rates in active learning and lecture-based courses, alongside results from standardized exam scores.

METHODS

The data for this project was taken in aggregate form over a five-year span encompassing Fall 2015 through Spring 2019 semesters, from the majors track general chemistry course sequence, Introductory Chemistry (Chemistry 22), General Chemistry I (Chemistry 1A) and General Chemistry II (Chemistry 1B) at **Blinded City College**. Students taking Chemistry 22 (n=1,318) numbered 199 enrolled in active learning classes (an inquiry-based classroom), and 1,119 enrolled in classes taught with traditional lecture-based pedagogy. For Chemistry 1A, out of 936 students, 209 were taught via active learning strategies (a flipped classroom) and 727 with traditional lecture, while data collected from Chemistry 1B consisted of 1,006 students from lecture-based courses and 359 from active learning classes, for a total of 1,365 students (**Table 1**). For this study, Asian and White students were examined alongside Hispanic students for success, progression (if a student enrolls in the following general chemistry course), and progression success (whether students successfully complete the next class) and completion (transfer or degree awarded) rates. The exclusion of African American students is due to the low number enrolled (nine total enrolled in the active learning classroom) in the Chemistry courses. Students that selected other were also excluded due to not knowing ethnicity. All students were chosen based on enrollment in the general chemistry classes. Every pertinent general chemistry course represented here was studied to remove the potential for bias in course and teacher selection. This data therefore represents the Chemistry Department as a whole and provides a clear window into best practices for a college level General Chemistry course sequence.

Table 1: Number of Students in Chemistry Courses taking Active Learning verse Traditional Teaching

	Active Learning Classroom	Traditional Lecture	Overall
Ethnicity			
Asian/White	440	1,583	2,023
Hispanic	265	1,013	1,278
Chemistry Course			
22	199	1,119	1,318
1A	209	727	936
1B	359	1,006	1,365

Experimental Design

The active learning classrooms were not advertised or marked as such in the online class schedule. Therefore, student selection was unbiased from the research side, leaving only room for bias in student selection of which instructor to take. All students were informed via the syllabus and in person on the first day of class that the teaching approach used would be a variation of active learning. Success, progression and completion data was compiled from **Blinded City College** Office of Instructional Effectiveness and the National Student Clearinghouse. All data was anonymous, leaving the researcher with only course numbers, term of class and student attempt number, gender, ethnicity, major and education level. No names or other personally identifiable information were collected. All data was stored in a password protected computer with access granted only to members of the research team and student assistants. **Table 2** shows the course sequence and active learning approach used for each Chemistry course.

Table 2: Active Learning Components in Sequence of Chemistry Courses at Community College

	Course description	Sample project	Active learning techniques
Chemistry 22	Introductory Chemistry	Inquiry Based Experimentation	Inquiry based learning
Chemistry 1A	General Chemistry I	Determine the chemical composition of seawater samples and write a formal report	Flipped class
Chemistry 1B	General Chemistry II	Water remediation of a heterogeneous mixture and create a poster presentation.	Project based learning with traditional lecture

Chemistry 22: Inquiry Based

Inquiry-based learning introduces new course material by means of a question which students must answer/solve on their own. Instead of beginning class with explanation of a procedure or lecture on the lab topic, the instructor first asks questions of the class regarding lab and allows students time to both think about and eventually understand how the question is relevant to the lab. This can be especially useful to the developing scientific mind.

When learning about empirical formula analysis for example, the lecturer can utilize inquiry-based learning by asking how one might go about identifying an unknown compound. The parameter is set whereas a lab worker performing a chemical reaction in which both reactant and product masses were obtained and compared, but students are not given the actual reaction details needed for the lab to commence, allowing them to research possible reactions which lead to the desired result and self-learn stoichiometric conversions which lead to a molar ratio of elements. The empirical formula concept is not introduced until after this inquiry-based activity, increasing student expectations for developing chemical analysis and calculation protocols. Integral to an inquiry-based approach is initial thinking and planning by the student which leads to increased chemical understanding prior to being shown the mathematical manipulations used in identifying formulas. The focus of learning is on conceptual chemistry as opposed to solving a chemistry problem.

The inquiry-based labs were designed to be scaffolded to prepare students for the subsequent General Chemistry I course (Chemistry 1A). A percent composition experiment in Chemistry 22 could be used in solving salinity of seawater for the Chemistry 1A lab project and the titration of acetic acid in vinegar principles can be modified to determine percent chloride composition in the seawater project. In this manner, Chemistry 22 inquiry labs were used to prepare students for a more advanced active learning experience in the next Chemistry course. In addition, inquiry labs were designed to introduce students to graphical and statistical analysis, such as preparing a standard curve, as well as tabulating mean and standard deviation.

Being that this course is the very first in the general chemistry sequence, data was gathered on the success, progression and progression success for students who completed Chemistry 22 after the first attempt, as well as students who initially failed and retook the course (**Table 3**). Comparing the active learning data to that from traditional lecture, Hispanic students enrolled in the former had a higher success rate, by 25.9 percentage points (76.4% verse 50.4%). The achievement gap between URM and non-URM students was closed significantly in the active learning courses, 13.3% as compared to 26.6%. Hispanic students in active learning classes progressed through to the next class at a higher rate than was seen in traditional lecture, the gap between the two groups at 9.8 percentage points. it is important to note that progression success for all students in Chemistry 1A sits approximately 10 percentage points lower in the active learning classes, but when students retake Chemistry 22 for a second time, success rate is 24.5 percentage points higher for Chemistry 22, the students progress to Chemistry 1A 20.1 percentage points more from the active learning course and succeed in Chemistry 1A at 26.7 percentage points higher than traditional-based students.

Table 3: Success, Progression and Progression Success (Chemistry 1A) for inquiry-based and traditional Chemistry 22 course

	Number of Students		Success	Progression	Progression Success
Active Learning	172	1st Attempt	85.5%	50.0%	62.8%
	27	2-3 Attempts	77.8%	55.6%	60.0%
	87	Asian/White	89.7%	54.0%	70.2%
	89	Hispanic	76.4%	48.3%	53.5%
Traditional	967	1st Attempt	67.5%	47.6%	75.2%
	152	2-3 Attempts	53.3%	37.5%	33.3%
	546	Asian/White	77.1%	52.4%	75.9%
	473	Hispanic	50.5%	38.5%	59.3%

Chemistry 1A: Flipped Class

The flipped classroom involves the student gaining prior knowledge of classroom material by reading textbook or watching on-line chemistry videos. This allows the professor to clarify topics in class as opposed to lecturing on easier chemistry topics, such as significant figures, electron configuration or basic Lewis Structures, which have been previously taught in the Introductory Chemistry course. Each flipped class began with a quiz which assesses student knowledge of assigned readings, and possible problem areas in student understanding which are then addressed by the instructor. Flipped classes encourage student independence and engagement by requiring personal review of the course material which encourages students to become better at learning the material and deters them from relying solely on teacher-centered lectures. The effectiveness of a flipped class has been improved by modern innovations and the internet: as more quality resources become available online, such as educational videos and Open Education Resources (OER), the student has more opportunity to excel. Ultimately, this method emphasizes the ability of each student to learn at a unique pace while the instructor fills the role of an expert, available to help navigate the challenges and obstacles inherent in the more complex chemistry problems (Hacisalihoglu 2018).

This flipped classroom approach was instituted in Chemistry 1A seeing as students previously enrolled in the preparatory Chemistry 22 course should already have a basic understanding of principles needed. The flipped class pedagogy allows them to reinforce chemistry principles from said previous course through active on-line lectures and textbook reading assignments, freeing up time in class to focus on more advanced, challenging chemistry topics and problems through class activities and student presentations.

In class activities were used to increase student enjoyment and understanding of chemistry topics. Laboratory consisted of inquiry-based experimentation and a semester long project analyzing salinity, chlorides and phosphates from Southern California tidepools seawater, bringing real world applications to the chemistry classroom. Students formed a hypothesis on how biological or geological aspects of the tidepool affect the chemical makeup of the seawater by drawing from current scientific literature. A scientific report was turned in at the end of the semester, with rough drafts due on weeks 6, 9 and 12. A day was set aside before the submission deadline for instructor feedback and peer review to better simulate the process of scientific writing as opposed to turning in a graded first draft with little to no chance for revisions.

Data was collected on the success, progression and progression success (percent of students that successfully completed Chemistry 1B). Analysis was performed on Asian/White students and Hispanic students (**Table 4**). Compared to a traditional class, Asian/White students succeeded by 16.9 percentage points higher in the flipped classroom. However, there was drop in this group's student success in the subsequent Chemistry 1B course (84.1% for traditional, and 75.3% for active learning students). Hispanic students succeeded by 34.4 percentage points more in the flipped class versus the traditional Chemistry 1A course (89.1% versus 54.7%). Out of thirty-six students who enrolled in Chemistry 1B, 28 successfully completed, 77.8% compared to only 67.1% from the traditional lecture course. Also, only 33.2% of Hispanic students from the traditional lecture course enrolled in Chemistry 1B, compared to 56.3% of Hispanic students enrolled in the flipped class.

Table 4: Success, Progression and Progression Success (Chemistry 1B) for flipped classroom and traditional Chemistry 1A course

	Number of Students	Ethnicity	Success	Progression	Progression Success
Active Learning	130	Asian/White	96.2%	59.2%	75.3%
	64	Hispanic	89.1%	56.3%	77.8%
Traditional	420	Asian/White	79.3%	56.9%	84.1%
	247	Hispanic	54.7%	33.2%	67.1%

A comparison of American Chemical Society (ACS) Standardized Exam scores between students enrolled in the active learning class, and students nationwide was used to determine if flipped class students performed differently (**Table 5**). The mean (flipped class 39.6 verse 38.6 traditional) and median (flipped class 39.0 verse 38.1 traditional) were tabulated and statistical analysis using a two-tail t-test showed 95% confidence that students who were taught with flipped classroom pedagogy achieved the same mean ACS exam score when compared to the National mean ACS exam scores for General Chemistry I.

Table 5: Chemistry 1A American Chemical Society Exam scores and norms

	Number of Students	Mean	Standard Deviation	Median
Active Learning	127	39.6	12.0	39.0
ACS Norms	8969	38.6	12.5	38.1

Chem 1B: Project based learning

The active learning component for chemistry 1B allowed students to simulate solving real life chemistry problems. Students were introduced to Erin Brockovich, a legal clerk turned consumer advocate who successfully litigated a case against Pacific Gas and Electric for alleged hexavalent chromium (chromium VI) presence in the drinking water of residents in Hinkley, California. Hexavalent chromium is a known carcinogen and the potable water in Hinkley had a peak of 20 parts-per-billion, allegedly leading to the increased cancer rates in Hinkley residents. This real-life example of heavy metal contamination lead to the introduction for the metal ion remediation project.

Students in groups of three or four were given a heterogeneous solution containing sand, sodium chloride, iron (III) and copper (II) ions. They were then tasked with separating each mixture component by the end of the semester (hexavalent chromium was not used due to its carcinogenic behavior). Eight of fifteen laboratory sessions (each 4.5 hours long) were dedicated to the project (additional experiments utilized inquiry-based learning on kinetics, thermodynamics, electrochemistry, equilibrium and coordination compounds). Assessment of project success focused on experimental design and analysis of results via a poster presentation at semester's end. Students were not graded on successful separation of mixture, but on forming a conclusion based on data collected from the experiment and developing future experimental procedures they would have used to optimize remediation. The aim is to enhance student critical thinking skills, curiosity, resilience and collaborative skills as opposed to a focus on rote memorization/knowledge, which is at the low end of importance when considering occupational needs (Davis 2019). Mastery of the former attributes prepare students for future professional success, thus the focus for Chemistry 1B project-based learning project.

Two success measures were utilized for Chemistry 1B, success rates of Asian/White students compared with Hispanic students (**Table 6**) and the ACS Chemistry 1B standardized exam (**Table 7**). Overall success rates were 89.2% for the project-based learning classroom, with no observable achievement gap between Asian/White students and Hispanic students. This is compared to an achievement gap of 25.2% for the traditional Chemistry 1B class, in which Asian/White students succeeded at a rate of 75.2% compared with a 50.0% success rate for Hispanic students. There was a 49.3% difference in success rates when comparing Hispanic students in the project-based learning class to traditional lecture. To ensure that rigor was maintained in the problem-based learning class, the second semester General Chemistry ACS exam scores were compared with ACS national norms. After using a two-tailed t-test it was concluded with 95% confidence that students from problem-based learning course achieved equivalent scores to national norms.

Table 6: Success rates for Chemistry 1B project based learning and traditional labs

Chem 1B	Number of Students		Success
Active Learning	223	Asian/White	89.2%
	112	Hispanic	89.3%
Traditional	617	Asian/White	72.9%
	293	Hispanic	50.5%

Table 7: Chemistry 1B American Chemical Society Exam scores and norms.

	Number of Students	Mean	Standard Deviation	Median
Active Learning	211	38.3	11.4	38.0
ACS Norms	>1000	37.9	10.9	37.3

The General Chemistry course sequence was chosen for study because 80.8% of students that finish Chemistry 1B achieve a desirable outcome (transfer or degree awarded) from **Blinded City College** science pathways compared with 36.2% of students in total (Student-Right-to-Know Rates). For this study, completion rates for active learning versus traditional classroom were compared. As seen in **Table 8**, students taking the project-based learning course at **Blinded City College** transfer or receive a degree 59.6% versus 54.9% in a traditional Chemistry 1B course. Hispanic students earn a completion 51.7% as compared to 40.6% from the traditional classroom. However, students who complete Chemistry 1B, by means of traditional lecture see a 13.1% positive percentage point increase in completion success among all students and a 39.9% percentage point increase among Hispanic students. Though active learning shows positive impact for increasing success of Hispanic students taking the course, more needs to be done to ensure that success translates to completion success. Addition of active learning components to additional disciplines, such as physics and math (both of which are lacking in professorial utilization of active learning) and increased student mentoring for students taking Chemistry 1B are options towards this goal which may better support students beyond completion of the active learning components in the general chemistry sequence alone.

Table 8: Completion percentages if Students completed based on Chemistry 1B

	Active Learning	Traditional
Taken 1B All Students	59.6% (106/178)	54.9% (617/1123)
Taken 1B Hispanic Students	51.7% (30/58)	40.6% (127/313)
Completed 1B All Students	70.2% (106/151)	83.3% (617/741)
Completed 1B Hispanic Students	58.8% (30/51)	92.7% (127/137)

Discussion

The data here presented is not only an analysis of individual chemistry courses, but also an opportunity to study effectiveness of teaching strategies used over the course of a general chemistry sequence. It is possible therefore to determine which, among the strategies employed, may be the point along the pathway that requires a change in teaching practices, whether in the active learning or traditional lecture course.

The point must be made that students in this study are from a community college. There are no limitations on acceptance, therefore anyone can enroll in courses as opposed to four-year universities with enrollment dependent on acceptance. Thus, it can be surmised that students enrolled in chemistry courses at community college will on average be less prepared for the academic rigor needed for chemistry coursework. This is not to say that community college students have fewer aspirations than their university counterparts. The greater difficulty within a community college is lack of student preparedness. Thus, most students begin their STEM pursuit enrolling in the introductory chemistry course, though it is not required.

Regarding Introductory Chemistry, students succeeded at a greater rate in the inquiry-based course. By contrast, when analyzing progression success in the subsequent Chemistry 1A course, the data indicates students from active learning classes were not as prepared as students taught with traditional lecture, as shown by their lower than desirable progression success. However, more students from the inquiry-based, Introductory

Chemistry class enrolled in Chemistry 1A (a 10-percentage point difference), suggesting that the inquiry-based course promoted a greater sense of belonging in STEM, which led to their continuation. Also of significance, students who initially failed, retook the course as a second or third attempt, drastically improved their success rates (77.8% versus 53.3%) and of these students who continued on to Chemistry 1A had a nearly 30 percentage point higher success rate in the next class (60.0% versus 33.9%) then second/third time traditional Chemistry 22 students. Though the sample number is small (only 15 students) this is an indicator that inquiry-based learning is most effective for those students with prior knowledge of the material. Therefore, an Introductory Chemistry course which promotes engagement through infusion of active learning and effectively prepares students for the General Chemistry sequence by way of a more traditional, teacher-centric focus on problem solving techniques, is a beneficial, powerful compromise, which could lead to both increased student engagement and success.

The flipped Chemistry 1A classroom successfully implemented active learning strategies to the benefit of all students, with Hispanic students achieving greater in-class success (a 34.4 percentage point improvement compared to the traditional classroom) and saw an increase in progression success by 10.7 percentage points compared to the same. However, this success appears to have come at the expense of Asian and White students who succeeded in Chemistry 1A at a higher rate (96.2% versus 79.3%) for the flipped classroom, but saw success drop by 8.8 percentage points in Chemistry 1B when compared to students from the traditional classroom. In fact, the Asian and White students had a 2.5 percentage point lower progression success rate than Hispanic students coming from the flipped class. The utilization of flipped classroom clearly promoted success among Hispanic students, but negatively impacted Asian and White students, a trend which may be attributed to a preferred teacher-centered approach to learning which is influenced by current and past learning experiences within their cultures (Loh 2017).

A flipped classroom requires students to self-engage for optimal success. Students are not always told exactly what to do. Worldwide, STEM education is faced with the impact of modern globalization and the need to be culturally sensitive to diverse learning styles (Yamada 2015). In order to assist students more accustomed to traditional instruction, on-line videos prepared by the instructor utilizing traditional lecture will better prepare lecture-oriented students as opposed to giving students a more open-ended assignment of textbook reading or on-line video examples, which were assigned for these flipped classrooms. In this manner, students who succeed through the more organized lecture style will have a greater chance of success within the classroom by watching the lecture videos prepared by their instructor.

Chemistry 1B focused on active learning utilized during lab. Once students transfer from community college, much of their STEM coursework will involve advanced experiments which require students to keep a science notebook, utilize critical thinking skills and design their own experiments. Traditional lecture becomes less important and by this time in their academic career, students ought to have developed the necessary study skills which the inquiry-based and flipped classes model. In other words, students at this juncture should have developed the metacognitive skills needed to better learn in the class and instructors should not have to use teaching tricks in lecture to get students actively engaged in their own education. Overall, approximately 89% of students in the project-based classroom succeeded compared with 70% in the traditional classroom. The largest difference is seen in the success of Hispanic students where the gap between success was nearly 40 percentage points (89.3% to 50.0%). Implementation of active learning in Chemistry 1B clearly promoted success for Hispanic students.

Unfortunately, the progression rates of students within the project-based class were not tracked. Chemistry 1B is one of the last essential community college science courses needed to transfer to a four-year university and for many STEM students their last chemistry course taken. Therefore, tracking to different universities and disciplines would present too many variables for analysis. However, completion rates can be tracked, which showed project-based learning enrolled students completing at 11.1 percentage points more than the traditional students. More in depth analysis of students that complete Chemistry 1B however, show over 13 percentage point higher community college completion rates for traditional-based students compared with problem-based learning students. Discussion on whether promoting student success within a course supersedes eventual overall completion needs to be addressed. Is it optimal to design an active learning course that promotes student success, but also sets up weaker students for future failure? Designing cross disciplinary (chemistry, physics, math and biology) active learning pathways would enhance the experience and allow students that thrive in this alternative learning setting to increase completion and better prepare them for their future in STEM.

One of the more prominent criticisms addressed by other community college instructors of active learning as a teaching strategy is supposed loss of rigor. In reality, rigor is transferred from high stakes exams, to development of the skills students will need for success in the STEM community and study habits which enable future success in higher level courses. The exams for the active learning classes were taken from a shared database of questions. However, the active learning course exams are worth 50% of the accumulated grade as opposed to 80% for the traditional lecture. The active learning students were also required to keep a lab notebook, write scientific research reports for each laboratory experiment and present their capstone research project as a poster at the conclusion of the semester. Lab reports for the traditional courses consisted of fill in the blank worksheets with one scientific report written that required no revisions or peer reviews. The instructors for active learning classes consistently worked with students in lab to keep students on track to finish the project. This one-on-one feedback did not occur as regularly within the traditional class unless a student actively engaged with instructor, a design that impacts low performing students most negatively. Traditional lecture exams are a means to assign grades, and in many cases are used only for this purpose. In the active learning classes discussed here exams are returned to students and in-class time is dedicated to post-exam review as a way to teach students the necessary content, and for discussion of study skills and habits so students will be better prepared for future exams. In order to demonstrate that chemistry knowledge and comprehension was not sacrificed to active learning, the ACS Standardized Exams were given as finals for Chemistry 1A and 1B courses. Students performed equally well on these standardized exams compared to national norms, showing mean scores slightly higher than national norms, which indicates that active learning students are just as prepared for, and knowledgeable of standard chemistry topics.

Far too often chemistry instructors lose the idea that science is fun. While the instructor's role is not to entertain, there are many opportunities throughout an academic semester for inclusion of engaging activities and experiments dealing with chemistry curriculum. These additions offer a chance to increase scientific curiosity and interest in students. As opposed to focusing all available time on solving chemistry problems, which can be tedious, a part of class time is spent demonstrating interesting aspects of science. This enhances student interest, engagement and ultimately increases success. Such a perspective shift is especially evident in students from underrepresented communities who many times feel ostracized and disinterested in chemistry due to low personal success and uninspiring instruction, which has led, in many cases. the student dropping the class. Overall, though, the problem does not seem to be one of preference for, or enjoyment of teaching stratagems, but one of effectiveness.

CONCLUSION

STEM classes are difficult in general and are traditionally associated with lower success rates among underrepresented minority groups. Students who are considered as URMs not only face the difficulties of learning science, technology, engineering, and mathematics, but racial biases, financial issues, discrimination, self-doubt, and alienation (Cabrera 2001; Minefee 2018). Despite these challenges faced at any given moment, URM students can excel in STEM related classes using active learning pedagogical teaching methods. As the results have clarified, using variants of active learning methods within a chemistry sequence of classes can drastically improve success and progression rates of Hispanic students. This is not only significant, but it is also beneficial to educators because foregoing research has only focused on the effectiveness of active learning methodology within individual classes, not an entire sequence within STEM education classes. Previous research has concluded that active learning improves URM student learning by 43% and increase success rates by 16% (Hacisalihoglu, 2018). Our results develop this idea further by incorporating variants of active learning within a chemistry class sequence and observing an average increase in success rates by 18.2% in Introductory Chemistry, 24.2% for General Chemistry I and 21.7% for General Chemistry II. Active learning is also an imperative aid to URM students' progression through their STEM education. Previous research has pointed to the fact that less than 50% of students who enter a STEM field during their freshman year of college receive a STEM related degree, and the percentage is much lower for URM students (Wilson 2012). The active learning classroom sequence employed at Blinded City College showed an increase progression rates of Hispanic students by 9.8% in Introductory Chemistry and 26.4% for General Chemistry I, as well as an increase of 11.1% completion. This further reveals to educators that incorporating active learning curriculum improves progression and success rates for all students.

Research thus far, while proving the success of active learning implementation within a classroom, has shown that underrepresented students in STEM see greater gains in retention, and success than do overrepresented students (Rainey 2019). In order to close the achievement gap of underrepresented students, an influx of resources is usually added to assist in the learning of underprepared and underrepresented students, at the expense of their more prepared counterparts. However, by making use of highly structured and interactive coursework, student success increases across the board.

As students enroll in General Chemistry II they are also moving into higher levels of mathematics and/or enrolling in the physics sequence, which are generally taught using a traditional lecture and also show low success rates, especially among URM students Previous research has indicated that an active learning approach to these classes increased student test scores, understanding of classroom concepts and student engagement, (Naron 2011; Majoka 2010; Armbruster 2017). This would indicate that implementing active learning strategies within physics and mathematics can help students reach their desired academic/career goals and increase the success of students in the STEM track. At the same time the students will have improved their real-life problem-solving skills and developed a community of like-minded students, an essential support group for progression through college STEM.

Utilizing inquiry-based learning in Introductory Chemistry, flipped classroom for General Chemistry I; and project-based learning for General Chemistry II allowed for a stepping stone approach in implementing active learning, as opposed to throwing students into the deep-end of active learning at the onset of their STEM pursuit. The inquiry-based approach to active learning is beneficial for an introductory chemistry class because most students will be interacting with the material for the first time and need more clear instruction in order to learn the necessary foundational chemistry knowledge/skills. A flipped classroom for

General Chemistry I allows students who have already learned foundational material through Introductory Chemistry to focus on self-efficacy and student engagement as opposed to teacher-centered lectures on already learned content. The project-based learning method used during General Chemistry II provides an environment where students are able to build upon their critical thinking and group dynamic soft skills needed for future STEM coursework and employment. The active learning pedagogy also contributes to closing the achievement gap in STEM.

Heterogeneity and ethnic diversity in an active learning classroom are associated with an overall positive effect on student outcomes, particularly in small group problem solving (Springer 1999). The community college, existing as a starting point for underrepresented students, many of whom are first generation college attendees (Chen 2013) is an ideal location to utilize active learning and increase student success. Increasing student engagement, self-efficacy and curiosity will lead to a more diverse, stronger STEM community.

REFERENCES

Adair, D, Jaeger, M, Price, OM (2018). Promoting Active Learning When Teaching Introductory Statistics and Probability Using a Portfolio Curriculum Approach. International Journal of Higher Education, 7(2), 175-188.

Armbruster, P, Patel, M, Johnson, E, et al. (2009). Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE—Life Sciences Education*, *8*(3), 203-213.

Andrews, TM, Leonard, MJ, Colgrove, CA, et al. (2011). Active Learning Not Associated with Student Learning in a Random Sample of College Biology Courses. CBE - Life Sciences Education, 10(4), 394-405.

Ballen, CJ, Wieman, C, Salehi, S, et al. (2018). Enhancing Diversity in Undergraduate Science: Self-Efficay Drives Performance Gains with Active Learning. CBE-Life Sciences Education, 16(4), 1-6.

Bangera, G, Brownell, SE (2017). Course-Based Undergraduate Research Experiences Can Make Scientific Research More Inclusive. CBE-Life Sciences Education, 13(4), 602-606.

Broekkamp, HB, Hout-Wolters, V (2007). The gap between educational research and practice: A literature review, symposium, and questionnaire. Educational Research and Evaluation, 13(3), 203–220.

Brown Center on Education Policy. (2018). *Improving community college completion rates by addressing structural and motivational barriers*

Cabrera, AF, Colbeck, CL, Terenzini, PT (2001). Developing Performance Indicators for Assessing Classroom Teaching Practices and Student Learning. Research in Higher Education, 42(3), 327-352.

Chen, X, Soldner, M (2013). STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001). Washington, DC: National Center for Education Statistics; Institute of Education Sciences; U.S. Department of Education: Retrieved November 15, 2019 from https://nces.ed.gov/pubs2014/2014001rev.pdf.

Davis, C, Fadel, C (2019). Business at OECD (BIAC) Position Paper for the proposed International Symposium on Employability and the Learner Profile (ISELP): Retrieved November 15, 2019 from https://curriculumredesign.org/wp-content/uploads/EDU-EDPC-RD-2019-14-Declassified.pdf

Demerci, C, Duzenli, H (2017). Formative Value of an Active Learning Strategy: Technology Based Think-Pair-Share in an EFL Writing Classroom. World Journal of Education, 7(6), 63-74.

Eddy, SL, Converse, M, Wenderoth, MP (2015). PORTAAL: A Classroom Observation Tool Assessing Evidence-Based Teaching Practices for Active Learning in Large Science, Technology, Engineering, and Mathematics Classes. *Cbe - Life Sciences Education, 14,* 2.)

Estrada, M, Burnett, M, Campbell, AG, et al. (2016). Improving Underrepresented Minority Student Persistence in STEM. CBE - Life Sciences Education, 15(3).

Foote, KT, Neumeyer, X, Henderson, C, (2014). Diffusion of research-based instructional strategies: the case of SCALEUP. International Journal of STEM Education, 1(10), 1-18.

Freeman, S, Eddy, SL, McDonough, M, et al. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences of the United States of America, 111, 8410-8415.

Gibbons, RE, Villafañe, SM, Stains, M, et al. (2018). Beliefs about learning and enacted instructional practices: An investigation in postsecondary chemistry education. *Journal of Research in Science Teaching, 55,* 8, 1111-1133.

Greco, JB (2018). Studio Format General Chemistry: A Method for Increasing Chemistry Success for Students of Underrepresented Backgrounds. ACS Symposium Series, 1301(8), 131-143.

Hacisalihoglu, G, Stephens, D, Johnson, L, et al. (2018). The use of an active learning approach in a SCALE-UP learning space improves academic performance in undergraduate General Biology. (J. P. Wouwe, Ed.) Plos One, 13(5) : e0197916. https://doi.org/10.1371/journal.pone.0197916.

Herrera, FA, Hurtado, S (2011). Maintaining initial interests: Developing science, technology, engineering, and mathematics (STEM) career aspirations among underrepresented racial minority students. Los Angeles: University of California, Los Angeles, Retrieved November 15, 2019, from Higher Education Research Institute website: http://www.heri.ucla.edu/publications-main.php

Hyun, J, Ediger, R, Lee, D (2017). Students' Satisfaction on Their Learning Process in Active Learning and Traditional Classrooms. International Journal of Teaching and Learning in Higher Education, 29(1), 108-118.

Kerrigan, J (2017). Active Learning Strategies for the Mathematics Classroom. College Teaching, 66(1), 35-36.

Lamb, R (2015). Development of a cognition-priming model describing learning in a STEM classroom. Journal of Research in Science Teaching, 52(3), 410-437.

Linn, MC, Palmer, E, Baranger, A, et al. (2015). Undergraduate research experiences: Impacts and opportunities. Science, 347(6222), 627-632.

Loh, CYR. Teo, TC (2017). Understanding Asian Students Learning Styles, Cultural Influence and Learning Strategies. Journal of Education & Social Policy, 7(1), 194-210.

Majoka, MI, Dad, MH, Mahmood, T (2010). Student team achievement division (STAD) as an active learning strategy: Empirical evidence from mathematics classroom. *Journal of Education and Sociology*, *4*, 16-20.

Marra, RM, Jonassen, DH, Palmer, B, et al. (2014). Why Problem-Based Learning Works: Theoretical Foundations. Journal on Excellence in College Teaching, 25(3&4), 221-238.

Minefee, I, Rabelo, VC, Stewart, OJ, et al. (2018). Repairing Leaks in the Pipeline: A Social Closure Perspective on Underrepresented Racial/Ethnic Minority Recruitment and Retention in Business Schools. Academy of Management Learning & Education, 17(1), 79-95.

Minhas, PS, Ghosh, A, Swanzy, L (2012). The effects of passive and active learning on student preference and performance in an undergraduate basic science course. Anatomical Sciences Education, 5(4), 200-207.

Missildine, K, Fountain, R, Summers, L, et al. (2013). Flipping the Classroom to improve Student Performance and Satisfaction. Journal of Nursing Education, 52(10), 597-599.

Mupira, P, Ramnarain, U (2018). The effect of inquiry-based learning on the achievement goal-orientation of grade 10 physical sciences learners at township schools in South Africa. *Journal of Research in Science Teaching, 55,* 6, 810-825.

Naron, C (2011). *Active learning in the physics Classroom*. Walden University.

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. The Internet and Higher Education, 25, 85-95.

Omelicheva, MY, & Avdeyeva, O (2008). Teaching with Lecture or Debate? Testing the Effectiveness of Traditional versus Active Learning Methods of Instruction. PS: Political Science and Politiics, 41(3), 603-607.

Owens, DC, Sadler, TD, Barlow, AT, et al. (2017). Student Motivation from Resistance to Active Learning Rooted in Essential Science Practives. Research in Science Education, 9688, 1-25.

Peine, A, Kabino, K, Spreckelson, C (2016). Self-directed learning can outperform direct instruction in the course of a modern German medical curriculum - results of a mixed methods trial. BMC Medical Education, 16.

Rainey, K, Dancy, M, Mickelson, R, (2019). A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions to major in STEM. International Journal of Stem Education, 6(6), Retrieved November 15, 2019 from https://doi.org/10.1186/s40594-019-0159-2.

Schmidt, HG, Rotgans, JI, Yew, EH (2011). The process of problem-based learning: what works and why. Medical Education, 45(8), 792-806.

Schmidt, HG, van der Molen, HT, te Winkel, WWR, et al. (2009). Constructivist, problem-based learning does work: A meta-analysis of curricular comparisons involving a single medical school. Educational Psychologist, 44(4), 227-249.

Springer, L, Donovan, SS, Stanne, ME (1999). Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis. Review of Educational Research, 69(1), 21-51.

Terhart, E (2013). Teacher resistance against school reform: reflecting an inconvenient truth. *School Leadership & Management, 33,* 5, 486-500.

Tight, M (2019). Systematic reviews and meta-analyses of higher education research. European Journal of Higher Education, 9(2), 133-152.

University of California (2019). Undergraduate admissions summary. From University of California: https://www.universityofcalifornia.edu/infocenter/admissions-residency-and-ethnicity

Vanderlinde, R, van Braak, J (2010). The gap between educational research and practice: Views of teachers, school leaders, intermediaries and researchers. British Educational Research Journal, 36(2), 299-316.

Wilson, ZS, Holmes, L, deGravelles, K, et al. (2012). Hierarchical Mentoring: A Transformative Strategy for Improving Diversity and Retention in Undergraduate STEM Disciplines. Journal of Science Education and Technology, 21(1), 148-156.

Yamada, A (2015). Changing Dynamics of Asia Pacific Higher Education Globalization, Higher Education Massification, and the Direction of STEM Fields for East Asian Education and Individuals. In: Collins, C.S., and Neubauer, D. E. (eds), Redefining Asia Pacific Higher Education in Contexts of Globalization: Private Markets and the Public Good, NY: Palgrave Macmillan, 117-128.